THE INVERTEBRATE CAVE FAUNA OF TASMANIA: ECOLOGY AND CONSERVATION BIOLOGY

by

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This thesis contains no material which has been accepted for the award of any other higher degree or graduate diploma in any tertiary institution, and to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Stefan Eberhard

Stefan Eberhard, August 1992

Summary

The invertebrate cave fauna of Tasmania is reviewed, based on collections from more than 130 caves in 31 karst areas. These totals represent approximately 14% of the known caves and about one half of the cavernous karst areas in the State. The distributions, ecological and conservation status of all taxa are discussed. More than 150 species, representing some 130 families in five phyla were identified. Species in at least 34 genera can be classified as troglobites or stygobionts. The fauna includes rare species, and species which are phylogenetic relicts, or have Gondwanaland affinities. Many taxa are undescribed.

More so than for mainland Australia, the Tasmanian cave fauna shows a pattern of similarity with the cave faunas of other glacial and periglacial regions such as New Zealand, Japan, United States and Europe. The disjunct distribution patterns shown by some genera of harvestmen and beetles support the Pleistocene-effect theory to explain the evolution of terrestrial troglobites. The cave stygobiont fauna includes species of syncarids, amphipods, heteriids, phreatoicids, flatworms and hydrobiid molluscs. At least the amphipod component of this fauna did not develop from hypogean ancestors, but probably colonised caves from adjacent surface waters.

Tasmania has the richest cave faunal assemblages in temperate Australia, with more than 70 taxa, consisting of more than 15 cave obligate species, recorded from some karst systems. Non karstic caves, such as dolerite boulder caves, also contain troglobitic species. Geological structure directly affects cave species diversity and ecological complexity. There is a general relationship between cave size and density, and species richness. Size of the karst area, vertical relief of the limestone outcrop and the type of surface vegetation also influence biodiversity in caves.

Some populations of cave invertebrates in Tasmania are 'vulnerable' or 'endangered', whilst others have recently become extinct. They are threatened by limestone quarrying, forestry operations, agricultural practises and recreation. The effect of quarry operations on Bradley Chestermans Cave include sedimentation, gross pollution and local extinction of aquatic fauna. Quarry run off has caused depletion of populations of aquatic snails in the Exit Cave system. Management requirements for Kubla Khan Cave include the protection of sensitive habitats from the impacts of cave visitors. Twenty eight sites of special conservation value are listed. Conservation and management initiatives for Tasmania are discussed, including collecting ethics, vulnerable habitats and species, and minimum impact caving techniques.

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Contents

CHAPTER 1 INTRODUCTION

1.1 Background

Tasmanian caves have a long history of biological investigation. The first species described was the Tasmanian Cave Spider, *Hickmania troglodytes* (Higgins & Petterd 1883). In 1895 an article published in *Scientific American* referred to the spectacular glow-worm display in Mystery Creek Cave (Anon. 1895). Lea (1910) described three species of beetle from this cave, and a fourth species from Scotts Cave. One of these, *Idacarabus troglodytes,* was the first troglobitic beetle known from Australia. Sloane (1920) described another species of beetle from Bottomless Pit.

A lengthy hiatus followed this early work. In 1946, organised speleology was established in Australia with the formation of the Tasmanian Caverneering Club. It was some years, however, before biospeleological research became re-established when Hickman (1958) described a troglobitic harvestman, *Manoxyomma cavaticum* (now *Hickmanoxyomma cavaticum*). Scott (1960) reported on a "White Fish" caught in Kubla Khan, which proved to be a very pale, feebly pigmented specimen of the introduced trout, *Salmo trutta.* This work was followed with the description of the oniscid isopod, *Echinodillo cavaticus* Green 1963, and a report on the subterranean occurrence of *Anaspides tasmaniae* (Williams 1965).

By the late nineteen sixties and through into the early seventies there was an upsurge of interest in the State's cave fauna, resulting in published descriptions of pseudoscorpions (Dartnall 1970), beetles (Moore 1967, 1972a, 1972b, 1978) and crickets (Richards 1964, 1967a, 1967b, 1968a, 1968b, 1969, 1971a, 1971b, 1972, 1974). Much of this material relied upon the collecting efforts of A. & T. Goede (1973a, 1973b, 1974a, 1974b), but also B. Cockerill, K. Kiernan and A. Terauds. At this time also, there was an interest in cave harvestmen (Hunt 1972a) and cave spiders (Gray 1973a), plus an interest in the invertebrate cave fauna as a whole (Goede 1967, 1972).

An indication of the existence of a diverse subterranean aquatic fauna was given by Goede (1967), and Lake & Coleman (1977). This was followed with the description of a stygobiontic crustacean, *Eucrenonaspides oinotheke,* (Knott & Lake 1980).

This brief review shows that much of this early work consisted of taxonomic descriptions of species. The only ecological study was that of Richards & Ollier (1976), who produced a species list and food web for the Ida Bay caves.

Recent work has concentrated on producing baseline inventories of species for particular karst areas (Clarke 1989a; Eberhard 1987a, 1988a, 1989). Concurrently, there has been a demand for information on the biological resources of caves, for conservation and land management purposes (Eberhard 1990a, 1990c; Houshold *et al.* 1988). To date, published descriptions of the many new taxa discovered on these surveys have been limited to harvestmen (Hunt 1990), spiders (Forster *et al.* 1990) and molluscs (Ponder 1992).

For many years it had been widely assumed that troglobites were poorly represented in the continental Australian cave fauna (Hamilton-Smith 1967). Moore (1964) suggested that increasing aridity of the continent, and dehydration of cave systems, might have caused the extinction of a supposed earlier fauna. For other reasons, obligate cave animals were thought to be largely absent in tropical caves worldwide (Vandel 1965). Nevertheless, both Hamilton-Smith (1967) and Moore (1972b) recognised the biospeleological potential of Tasmania because it appeared to present a pattern of similarity with the cave faunas of other glacial and periglacial regions, for example New Zealand, Japan, United States and Europe, both in the taxa represented and in the distributional patterns of species. However, the inaccessibility of many Tasmanian (and tropical Australian) caves and the physical difficulty of exploration, have severely limited the amount of collecting which has been done. Tropical caves in Australia, and elsewhere, are now known to hold diverse troglobitic faunas (e.g. Howarth 1988; Humphreys *et al.* 1989), including one site in northern Queensland which ranks amongst the richest in the world (Malipatil & Howarth 1990).

1.2 Cave biology and the scientific value of caves

Beyond the twilight zone, the cave habitat is characterised by total darkness. Compared to the surface, the cave environment remains relatively stable, with an almost constant temperature, high relative humidity and an extremely low rate of evaporation. Food supplies in caves are often unpredictable and few animals can survive there, but those that do are often highly specialised and cannot live anywhere else.

Animals which live obligatorily in caves, and other similar subterranean habitats (e.g. interstitial habitats), are collectively referred to as troglobites. Troglobites often show morphological specializations such as degeneration or loss of eyes, depigmentation, attenuation of appendages, hypertrophy of sensory structures and increase in body size. Many troglobites are descendants of troglophiles, facultative cave inhabitants able to live in or outside caves (Barr & Holsinger 1985).

With some exceptions, the geographic ranges of troglobitic species are generally small and sometimes island-like (Holsinger 1988). They tend to be correlated with separate exposures of cavernous rocks. In many limestone cave regions, closely related species are found in adjacent karst areas or in cave systems separated from each other by some kind of physical barrier. Many cave faunas are very old, isolated relicts that survived in cave refugia long after their ancestors either became extinct or migrated elsewhere because of changing conditions on the surface. Explaining the origins and geographic distributions of troglobites has important implications for evolutionary biology (Holsinger 1988).

Food webs in cave ecosystems are relatively simple in comparison with most other systems, and they are often regarded as fragile and vulnerable to disturbance. This poses special problems for conservation and management (Davey 1984), and for the study of cave ecology. Cave studies can assist our understanding of more complex ecosystems, and therefore contribute to the development of fundamental ecological principles (Chapman 1983).

Karst may be significant in nature conservation terms by virtue of its scientific and National Estate value, its recreational importance, aesthetic considerations, historical associations, folklore or religious considerations (Kiernan 1989a). The conservation value of a number of Tasmania's caves and karst areas has been degraded in historical times through limestone quarries (e.g. Ida Bay), forestry (e.g. Junee - Florentine) and agricultural practises (e.g. Mole Creek). Other potential threats to cave biota include the impact of cave visitors. Some cave populations at Ida Bay and Flowery Gully have recently become extinct, and several others are 'endangered' or 'vulnerable'. The extent of these problems, combined with the recent discoveries, reported here, of a high biological diversity in Tasmanian caves, implies that more conservation - orientated research is urgently required.

1.3 Aims of this study

This study consists of two major parts; firstly, a survey of the invertebrates of Tasmanian caves in order to identify the species present, and secondly, an assessment of their conservation status, to identify sites of importance and allow discussion of management and protection measures. The first part involved collating existing information and making faunal collections from previously uncollected and poorly collected karst areas; this has already been reported (Eberhard *et al.* 1991). The detailed work plan involved the following components:

1) Locating and reviewing all existing literature on the Tasmanian cave fauna.
2) A systematic field sampling programme. Time constraints did not permit a survey of all the caves or karst areas in Tasmania. However, priority was given to poorly collected or unknown sites, as well as areas threatened by activities within their catchments.
3) All specimens collected were identified as far as possible. Some material was sent to appropriate specialists for complete identification or taxonomic description (see Appendix 3).
4) All specimens were curated in a collection of Tasmanian cave fauna, and this material was registered on a cave database. The collection was lodged at the Queen Victoria Museum and Art Gallery.
5) The information compiled included the distribution, ecological and conservation status, and biological significance of all cave invertebrate species.
6) The effect of limestone quarry operations on cave fauna was investigated.
7) Karst areas, caves or species with a high conservation value, or which are threatened by current land use practises were identified.
8) Minimum impact caving and scientific techniques were discussed.

1.4 Karst development in Tasmania

Tasmania is an island of 68 330 square kilometres, situated between 41 and 43 degrees latitude South and rising to a maximum elevation of 1617 metres. The climate is cool temperate with annual rainfall ranging from 500mm to 3600mm. The majority of karst areas are located in the western half of the State, which is characterised by high rainfall; the main vegetation types are temperate *Nothofagus* rainforest, wet *Eucalyptus* forests, sedgeland and alpine vegetation.

Karst is the term applied to a variety of distinctive landform and drainage features (e.g. caves and sinkholes) formed on rock that exhibits a high degree of solubility in natural waters (Jennings 1971). Karst gains its fullest expression on limestone, dolomite or evaporite bedrock. A karst system may be defined as all the caves developed within the same hydrological catchment, or possibly contiguous catchments. A karst area may contain one or more karst drainage systems. Karst features have been recognised from more than 105 localities in Tasmania (Kiernan 1988), and more than 1000 caves have been recorded; the distributions of karst areas are shown in Figure 1. The caves are developed predominantly in Ordovician limestone, Upper Precambrian and Lower Cambrian dolomites and limestones, and occasionally in Permian limestone and Pleistocene dune limestone (Kiernan 1980a). Pseudokarst and parakarst features include solution cavities in non-karst rocks, sea caves, soil piping tunnels, caves behind waterfalls, seasonal snow caves and boulder caves (Kiernan 1982c). Air temperatures in the caves range from 4 to about 12°C, but most caves approximate 9 to 10°C. Many of Tasmania's karsts lie marginal to, or within, areas which were covered by glacial ice during the

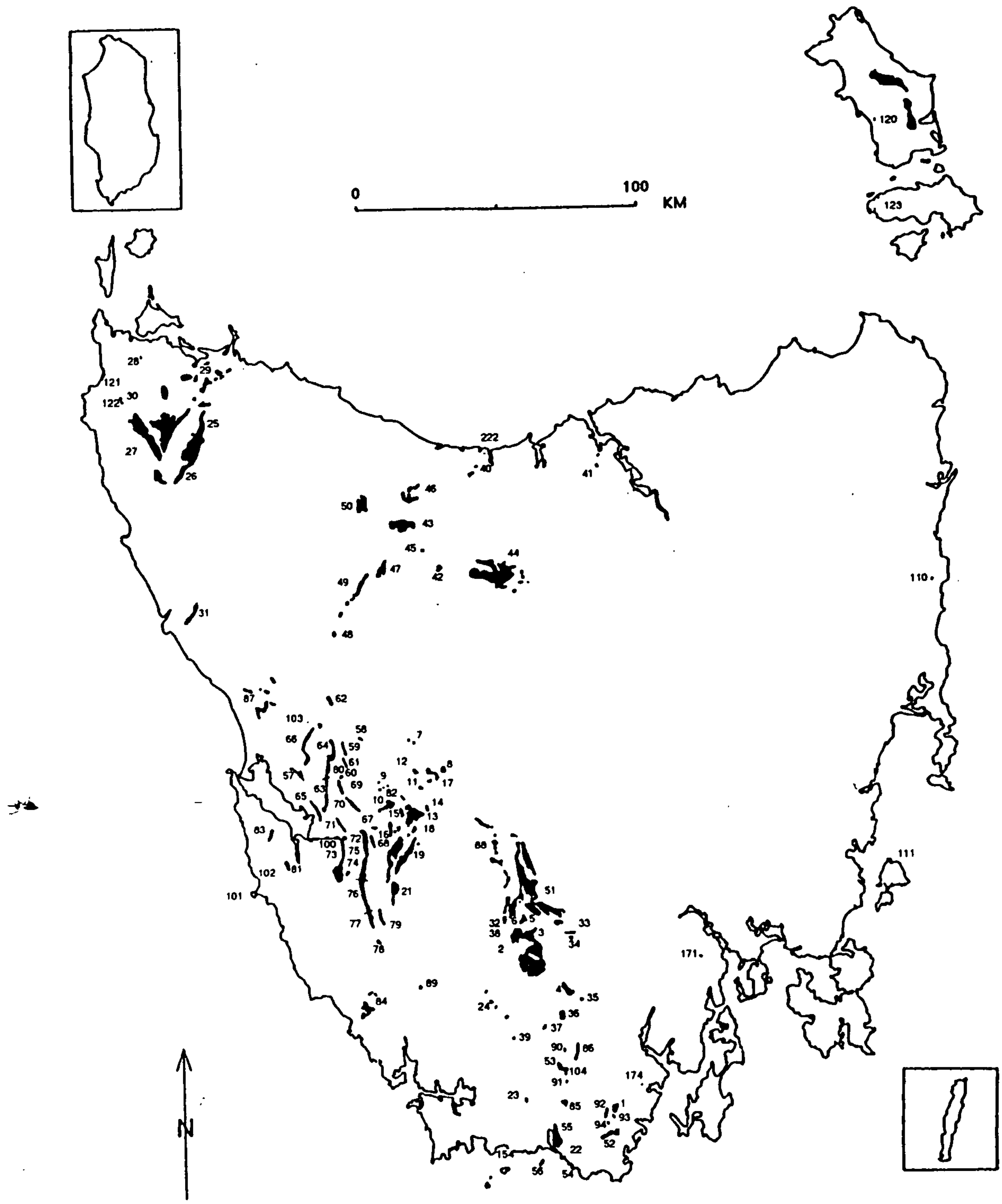


Figure 1. Distribution of karst areas in Tasmania after Kiernan (1988). Appendix 1 gives the key to the localities.

Cainozoic. Karstic processes in these areas were subject to massive variations of thermal regime, hydrological regime and clastic load during changes in climate. Other karsts were influenced by periglacial processes and fluctuations in base level (Kiernan 1982a).

The nomenclature of karst areas followed in this study is that adopted by the Australian Speleological Federation, and given in Kiernan (1988). Each karst locality is designated an area code; e.g. IB = Ida Bay. Cave names follow Matthews (1985). The majority of caves are tagged with a small metal plate, affixed at the entrance and bearing an identification number. Cave identity is recorded as the cave name, area code and tag number; e.g. Mystery Creek Cave (IB10). Some caves are unnamed, but do bear an identification tag. A few caves are named but not tagged; these caves are given an arbitrary identification number which is prefixed by 'x'; e.g. Newdegate Cave (H-x7). Other caves are both unnamed and untagged, and are referred to by their area code plus an unofficial number designated during the course of this survey; e.g. Mount Wellington: Cave 1 (WE-x1).

1.5 Methods

During the course of my field work, 39 caves in 17 karst areas were sampled intensively for biological specimens. The sampling programme was designed to encompass the range of rock types represented, as well as to cover the widest range geographical areas possible (viz. south-east, north-east, north-west and south-west Tasmania). Priority was given to sampling caves which may have been threatened in some way, and to caves which were already known to possess a high biological conservation value. Occasional collections made by me since 1980 are included also. These occasional collections came from 55 caves in 7 karst areas. Also included are collections made in the Western Tasmania World Heritage Area under the Directed Wildlife Research Programme of the Department of Parks, Wildlife and Heritage; these include 38 caves in 13 karst areas (Eberhard 1987a; 1988a; 1989). In addition, biological data were obtained from the literature, or from other scientists, to give 133 caves from 31 karst areas. These totals represent approximately 14% of the known caves and about 56% of the cavernous karst areas in Tasmania. Two dolerite boulder caves from a pseudokarst area at Mt Arthur were also sampled.

In those caves that were sampled intensively, all recognised habitats were searched for specimens. These included damp clay and silt banks, organic detritus (wood, leaves and litter, guano and dung, bones and carcasses), tree roots, calcite formations, crevices in walls, watercourses, pools fed by drips and seeps, and the undersides of stones. Sampling encompassed the four zones recognisable in the cave environment: the cave entrance, the twilight zone, the transition zone, and the deep cave zone.

Berlese Funnels were utilised for the extraction of specimens from terrestrial leaf litter samples. Trapping techniques (drift nets, tangle nets, crayfish rings) and baits (sweet potato or blue vein cheese) were employed occasionally. Aquatic interstitial environments were sampled by excavating a hole approximately 150 to 200 mm deep in stream bank sediments, and then straining the water that collected through a 0.5 mm mesh. The majority of records, however, are based on collections made directly from the substrate, aided only by small brushes, forceps, hand nets or suction devices. Collecting efforts were focused on all elements of the cavernicolous fauna, particularly troglobites and troglophiles (see below). Surface habitats were sampled on an *ad hoc* basis in order to obtain specimens for comparison with those taken from nearby caves. This study is essentially concerned with macroscopic forms (>1mm).

1.6 Definition of terms

Any animal living in a cave can be defined as a *cavernicole*. The traditional Schiner-Racovitza system for the ecological classification of cavernicoles consists of three major categories (Vandel 1965). *Troglobites* are species which are obligatory cavernicoles and, in nature, are unable to survive except in caves or similar hypogean habitats. Troglobites are often distinguished by morphological specializations called *troglomorphisms*, which may include loss or rudimentation of eyes and pigment, and attenuation of the body, appendages, or sensory hairs (Holsinger & Culver 1988). Some workers (e.g. Vandel 1965) utilise the term *true cavernicole* as a synonym of troglobite. *Troglophiles* are facultative cavernicoles. They are found living permanently, and successfully completing their life cycles, in caves, but they also do this in suitable epigean or endogean habitats. *Trogloxenes* are species habitually found in caves but they do not complete their whole life cycle there and must return periodically to the surface or entrance zone for food. A further category are the *Accidentals*, which are species that wander, fall, or are swept into caves. They survive for varying lengths of time, and larval forms may metamorphose to the adult, but further generations are not established within the cave. Modifications to this classification scheme have been proposed. For example, Hamilton-Smith (1971) subdivided troglophiles into *first level* and *second level* types, a first level troglophile being a species which has also been recorded from epigean habitats, whilst those known only from caves, but not showing any clear troglomorphisms, were termed second level troglophiles.

Edaphobites are deep-soil dwelling (or endogean) species that frequently display troglomorphisms and may sometimes occur in caves. As described by Jefferson (1976), the *endogean* domain is the soil extending down to the greatest depth to which the roots of vegetation may penetrate. Some workers extend the definition to include the ground litter layer and its fauna. Typically epigean species which shelter in the entrance and twilight zones are referred to by Vandel (1965) as the *parietal association*.

Aquatic subterranean habitats with a specialized fauna which are not restricted to karst areas include crayfish burrows, interstitial media and the hypotelminorheic medium. *Pholeteros* is a term used to refer to the fauna found in the burrows of freshwater crayfish (Lake & Coleman 1977). As defined by Vandel (1965), the *hypotelminorheic medium* may be observed in mountainous regions where deposits of silt or clay are covered with dead leaves, humus, moss or other vegetation, These deposits are traversed at a depth of some centimetres by tiny streams of water which may contain species formerly regarded as true cavernicoles. The interstitial medium covers a variety of different environments including the *hyporheos* (water flowing in stream beds) and the region occupied by groundwater (*phreas*). The term *troglorhythrostygal* refers to the interstitial accompanying running water in a cave system (Botosaneanu 1986). Obligate subterranean species living in hypogean waters, whether truly interstitial or not, may be referred to as *stygobionts* or *phreatobites*. Facultative species are termed *stygophiles*. The karst aquifer can be subdivided into three distinctive hydrological zones which correspond to major subsurface habitat types (Culver 1982). The lowest of these is permanently flooded (phreatic zone), above this is an intermittently flooded zone (active vadose zone) and an upper, dry zone (inactive vadose zone).

The following abbreviations are used in this thesis: Tb = troglobite, Tp = troglophile, Tx = trogloxene, Ac = accidental, Ed = edaphobite, Pa = parasite, Sb = stygobiont, Sp = stygophile, TpII = second level troglophile (*sensu* Hamilton-Smith 1971).

The four cave zones from which samples were obtained may be defined as follows: the *entrance zone* where the surface and underground environments meet each other; the *twilight zone* where light progressively diminishes to zero; the *transition zone* where light is non existent but the environmental effects from the entrance are still felt; and the *deep cave zone* where environmental conditions are stable. Remote from entrances, deep portions of caves are dark, with fairly constant temperature (usually approximating the mean annual surface temperature), relative humidity often near saturation, and an extremely low rate of evaporation (Barr & Holsinger 1985). The extent of the different zones depends on the size, shape and location of the entrance(s), on the configuration of the cave passages, and on the subterranean moisture supply (Bousfield & Howarth 1976). Although not identified yet in Tasmanian caves, a fifth zone has recently been recognised in North Queensland caves by Howarth (1988). The *stagnant air zone* is characterised by elevated carbon dioxide concentrations and depressed oxygen levels. This zone may support a unique cave-adapted community.

Terrestrial troglobites are usually restricted to the deep cave zone, and the most critical environmental factor governing their distribution appears to be the stable saturated atmosphere (Howarth 1982). However, many troglobites migrate closer to the entrance, even into the twilight zone, under suitably humid conditions and further into the cave as the passages dry out (Howarth 1983). Aquatic troglobites are sometimes found in surface waters which emerge from karst springs.

CHAPTER 2 REVIEW OF THE TASMANIAN CAVE FAUNA

2.1 Introduction

This section surveys the full range of invertebrate animal groups found in Tasmanian caves, briefly reviewing what is known of their biology and listing all records of collections. More than 150 species of animals, representing some 130 families and 112 genera, have been identified from caves in the study area. However, much of the material collected remains unidentified.

Following the systematic scheme of Marshall and Williams (1981), the taxa represented consist of five phyla with eight major sub-groups: Platyhelminthes (Tricladida: Turbellaria), Nemertini, Aschelminthes (Nematoda and Nematomorpha), Annelida (Oligochaeta and Hirudinea), and Arthropoda (Onycophora, Chelicerata and Mandibulata). Arachnids (31 genera in 28 families belonging to 4 orders), crustaceans (28 genera in 17 families belonging to 7 orders and 3 sub-classes); and insects (54 genera in 50 families belonging to 15 orders and 4 sub-classes) are well represented, although these figures partly reflect the good taxonomy which is available for some of these groups.

A large proportion (90%) of the recorded genera are arthropods, and most of the cave obligate species belong to the Arthropoda. Troglobites or stygobionts are represented in the following groups: Opiliones (7 genera); Pseudoscorpionida (1 genus); Araneae (7 genera in 7 families); Syncarida (4 genera); Isopoda: Oniscoidea (1 genus); Isopoda: Phreatoicoidea and Asellota (2+ genera); Amphipoda (3 genera); Diplopoda (1+ genera); Collembola (2 genera in 2 families); (possibly) Diplura (1 genus); Hemiptera; Psocoptera; Coleoptera (3 genera); Mollusca: Gastropoda: Hydrobiidae (1 genus).

In the following section the Tasmanian cave fauna is reviewed group by group. The same information is presented in Appendix 4 as a listing by karst area. Distribution maps are presented for groups

2.2 Phylum Platyhelminthes: Turbellaria: Tricladida

Free-living flatworms recorded from Tasmanian caves belong to the Order Tricladida, and include both terrestrial and freshwater representatives. Little of the material has been identified and the ecological status of the freshwater taxa remains unclear.

2.2.1 Suborder Paludicola

Freshwater flatworms (Suborder Paludicola) are commonly called planarians and are distributed in caves throughout the State. They can be found in seeps, streams and pools. Some taxa found in caves also occur in surface watercourses nearby. Other taxa appear at least superficially troglomorphic, such as a small white species which lives in seepage pools deep inside the Ida Bay Potholes and the Salisbury River caves. Clarke (1989a) records an unidentified species of *Cura* from Bubs Hill.

Numerous cave obligate and stygobiontic species are known from the northern hemisphere (Gourbault 1986; Vandel 1965). Ball (1977) has described an interstitial species from Victoria.

Planarians are abundant in some caves, especially those with a source of nutrient enrichment. Holsinger (1966) investigated the effects of organic pollution in Banners Corner Cave in Virginia, and found an exceedingly large population (by hypogean standards) of planarians and isopods. He suggested that cave planarians feed on faecal material and other organic detritus. A similar situation exists in Tasmania in Bradley Chestermans Cave (IB4) at Ida Bay which is polluted by organic and inorganic runoff from a limestone quarrying operation. The aquatic faunal assemblage in this cave is depauperate in comparison to unpolluted caves nearby, but there is a large population of planarians. The evidence given here supports the suggestion that planarians may be a useful indicator species of organic pollution in caves (Eberhard 1990a).

Distribution Records for Paludicola
Acheron River: Cave 1 (AR-x1)
Bubs Hill: Main Drain (BH8), Highway Holocaust (BH13), Thylacine Lair (BH203), Quarry Cave (BH205) (Clarke 1989a)
Cheyne Range: Cave (CR-x1)
Franklin River: Kutikina Cave (F34), Proina Cave (F51)
Hastings: King George V Cave (H-x6)
Ida Bay: Bradley Chestermans Cave (IB4), Comet Pot (IB98), Giotto Pot (IB104), Loons Cave (IB2), Arthurs Folly Cave (IB110) (Eberhard 1990a)
Junee-Florentine: Khazad Dum (JF4), Serendipity (JF344)
Loongana: Mostyn Hardy Cave (L4)
Lower Maxwell River: "Cricket Cave" (LM-x1)
Mole Creek: Little Trimmer Cave (MC38)
Mount Ronald Cross: Capricorn Cave (MR204)
Nicholls Range: Bill Nielson Cave (NR1)
Redpa: Cow Cave (R204)
Vanishing Falls: Salisbury River Cave, Alley Pot

2.2.2 Suborder Terricola

Terrestrial flatworms (Terricola) are rarely found deep inside caves, and none of the taxa appear to be restricted to caves. Although coloured white, the geoplanid *Geoplana typhlops* is not troglomorphic and is recorded from forest litter close to cave entrances at Bubs Hill (Clarke 1989a). Apart from this direct association with endogean habitats, flatworms actively enter caves and may be found on the walls or floor in the twilight zone, or just beyond in the dark zone. These taxa may be trogloxenous. Occasionally, flatworms are found well into the dark zone. At Flowery Gully, a common pasture species (unidentified) has successfully invaded a cave (FG201) there.

Distribution Records for Terricola
Bubs Hill: caves BH5, BH7, BH13, BH16, BH203 (Clarke 1989a)
Cracroft: Judds Cavern (C1)
Eugenana: Sherrils Cave (E201)
Flowery Gully: Flowery Gully Cave (FG201)
Gray: Elephant Farm Cave (G-x2)
Ida Bay: Exit Cave (IB14), March Fly Pot (IB46), IB100
Junee-Florentine: Burning Down The House (JF402), Welcome Stranger (JF229)
Loongana: Mostyn Hardy Cave (L4)
Mole Creek: Kubla Khan (MC1), Little Trimmer (MC38)
Mount Wellington: Cave 1 (WE-x1), Cave 2 (WE-x2)

2.3 Phylum Nemertina

Freshwater nemertines are recorded from only three Tasmanian cave sites. In IB110 they occur in a small perennial watercourse deep underground.

Freshwater nemertines are rare animals (Williams 1980). Hoplonemerteans so far described from Australia are referable to the tetrastemmatid genera *Prostoma* and *Potamonemertes*. The former has a cosmopolitan distribution (Gibson & Moore 1971) while the latter is known only from New Zealand (Moore & Gibson 1973), and recently Tasmania (Hickman & Moore 1990). *Prostoma graecense* occurs in Tasmania, as well as mainland Australia (Greenslade 1985).

As far as is presently known, nemertines do not represent an important part of the world stygofauna. Apart from two definite stygobiont *Prostoma* spp. described from European caves, which have lost eyes and all pigmentation, and an interstitial form from New Zealand (*Potamonemertes percivali*), no morphological differences are seen between subterranean and epigean forms (Kirsteuer 1986).

Distribution Records for Freshwater Nemertina
Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)
Gray: Elephant Farm Cave (G-x2)
Ida Bay: Arthurs Folly Cave (IB110)

A single species of terrestrial nemertine, *Argonemertes australis*, is known from Tasmania, Queensland and Victoria (Moore 1975). A single specimen was collected from a wall in the dark zone of a cave (JF1) in Tasmania.

2.4 Phylum Aschelminthes

2.4.1 Nematoda

This group was not collected during this survey, but free-living macroscopic nematodes may be found in flood-deposited leaf litter in caves. These are likely to be epigean or endogean species swept underground during floods. Aquatic nematodes have been sighted occasionally in streams and pools. The identity and ecological status of Tasmanian cave nematodes is totally unknown.

Because nematodes display regressive morphological and anatomical characters, it is very difficult to distinguish stygobiontic from non-stygobiontic forms, but some species are known which are specialised to survive in the food-poor environment of stygal habitats (Eder 1986).

2.4.2 Nematomorpha

Members of this group, the horse-hair worms, have been recorded sporadically from pools, intermittent watercourses and flowstone surfaces in the dark cave zone. This group is known to be parasitic as juveniles in arthropods, but free-living and primarily aquatic as adults (Williams 1980). The worms found in caves may well be parasitising the arthropod fauna there. Clarke (1989a), for example, collected a specimen of *Gordius* sp. from beside an emaciated cave spider, *Hickmania troglodytes*.

Distribution Records for Nematomorpha
Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)
Ida Bay: unspecified caves (Clarke 1989b)
Junee-Florentine: Growling Swallet (JF36), Sesame I (JF210)
Precipitous Bluff: Cueva Blanca (PB4), Damper Cave (PB1)
Weld River: Weld River Arch

2.5 Phylum Annelida

Segmented worms recorded from caves belong to the Classes Oligochaeta and Hirudinea.

2.5.1 Hirudinea

In the Hirudinea, terrestrial leeches are recorded from caves only occasionally. They are accidental cavernicoles. They may be abundant in vegetation outside cave entrances, but rarely penetrate far underground. Leeches may be inadvertently carried underground by cavers; for example they are reasonably common in heavily visited caves such as Kubla Khan (MC1).

<u>Distribution Records for Hirudinea</u>
Junee-Florentine: Welcome Stranger (JF229)
Lower Andrew River: Cave 2 (LA-x2)
Mole Creek: Kubla Khan (MC1)

2.5.2 Oligochaeta

Oligochaetes, both terrestrial and aquatic, are widely distributed in Tasmanian caves, and may be locally abundant in damp mud and silt banks bordering streams and pools. They may be introduced in mud, silt or litter washed underground by flooding or filtration. Other taxa, most probably accidental cavernicoles, are found in litter at the base of entrance shafts, and in leaf litter deposited underground by flooding. Partial identifications are available from the Bubs Hill and North Lune karst areas, where the groups recorded are Enchytraeidae, Megascolecidae (*Perionychella* sp.), and Lumbricidae (*Lumbricus* sp.) (Clarke 1989a, 1989b).

Terrestrial and semi-terrestrial "earthworms" are relatively abundant in organically enriched siltbanks of caves accepting drainage from agricultural land. This is the case at Flowery Gully and Gunns Plains. These two sites (FG201 and GP1) also contained populations of tubificid oligochaetes, found in the stagnant pools of streamways. Tubificids are indicators of hypoxic conditions and at least mild organic pollution (Bayly & Williams 1981).

A review of the world's continental oligochaete stygofauna is given by Juget & Dumnicka (1986).

<u>Distribution Records for Oligochaeta</u>
Bubs Hill: Minimoria (BH202), BH16, Fishing Pond (BH2), Thylacine Lair (BH203) (Clarke 1989a)
Cracroft: Judds Cavern (C1)
Flowery Gully: Flowery Gully Cave (FG201)
Franklin River: Kutikina Cave (F34), Proina Cave (F51)

Gunns Plains: Gunns Plains Tourist Cave (GP1)
Ida Bay: Mystery Creek Cave (IB10), Loons Cave (IB2), Skyhook Pot (IB34)
Junee-Florentine: Owl Pot (JF221), Growling Swallet (JF36), Rift Cave (JF34), Khazad Dum (JF4), "Wherrets" Cave (JF-x6)
Loongana: Mostyn Hardy Cave (L4)
Mole Creek: Kellys Pot (MC207), Kubla Khan (MC1), Croesus Cave (MC13)
Nicholls Range: Bill Nielson Cave (NR1)
North Lune: Spider Den (NL3) (Clarke 1989b)
Redpa: Glue Passage Cave (R202)
Trowutta: Trowutta Arch (T201)
Vanishing Falls: Salisbury River Cave

2.6 Phylum Arthropoda

2.6.1 Sub-phylum Onycophora

Ooperipatellus insignis is sometimes recorded from caves, where it may wander into the dark zone from surrounding forest habitats. To date it is known from caves at Acheron River (AR-x2) and Bubs Hill (BH203). Both these locality records extend the mid western distributional range for the taxon as given by Tait & Briscoe (1987). In BH203 at Bubs Hill, a number of individuals have been seen in the cave at one time. An unidentified species, possibly *O. insignis,* is known from a cave in Risbys Basin at Maydena.

Of some interest is the Blind Velvet Worm, an apparently troglomorphic peripatopsid that is white in colour and totally lacking eyes. It has a restricted distributional range of less than 200 square kilometres (Mesibov 1988), which coincidentally is centred on the Gray-Mount Elephant karst area. This animal normally lives in rotting logs but searches of the caves in this area failed to reveal any specimens (Eberhard & Eberhard 1989).

Elsewhere, two cave dwelling species which are eyeless and unpigmented occur in South Africa and Jamaica, whilst an eyeless but pigmented species is recorded from scrub jungle in the Himalayan foothills (Lawrence 1931; Peck 1975). Howarth (1988) reports the occurrence of a possibly troglobitic species from a lava tube in North Queensland. In New Zealand, at least two epigean species of *Peripatoides* enter caves, with a permanent colony known from Twin Forks Cave in the South Island (Ruhberg 1985).

Distribution Records for Onycophora
Acheron River: Cardia Cave (AR-x2)
Bubs Hill: Thylacine Lair (BH203)
Risbys Basin: Ray Bender's Cave

2.6.2 Sub-phylum Chelicerata
Class Arachnida

Order Opiliones

Tasmania has a rich fauna of both epigean and cavernicolous harvestmen (G. Hunt pers. comm.). Harvestmen belonging to the suborders Palpatores and Laniatores are both recorded from caves. Among the Palpatores, family Megalopsalididae, *Spinicrus nigricans* and *Spinicrus* sp. shelter inside cave entrances. They represent part of the parietal association. The dominant cavernicolous group includes both troglophiles and troglobites belonging to the suborder Laniatores, family Triaenonychidae. The genera recorded are *Hickmanoxyomma, Mestonia, Nuncioides, Lomanella, Calliuncus, Odontonuncia, Paranuncia, Glyptobunus, Phoxobunus, Notonuncia, Nucina,*and *Leionuncia.* Troglobitic forms are present in *Hickmanoxyomma, Mestonia, Nuncioides, Notonuncia, Glyptobunus* and *Lomanella. Leionuncia* includes a possibly troglobitic form.

The endemic genus *Hickmanoxyomma* contains Tasmania's best known cavernicolous harvestmen, recently the subject of a comprehensive taxonomic revision by Hunt (1990). The distribution patterns and evolution of this species complex are discussed later in this thesis, and by Kiernan and Eberhard (in press). The distribution of the genus extends from Precipitous Bluff in the south of the State, to Mole Creek, Flowery Gully and Scottsdale in the north. Seven species are presently described, and further undescribed material is known from Vanishing Falls, Bubs Hill, the Andrew, and the Franklin River. Hunt recognises three species groups: the *cavaticum* species group, consisting of four species from southern Tasmania; the *tasmanicum* group with two species from northern Tasmania; and the monospecific *cristatum* group from Precipitous Bluff. With one exception, all these species appear to be confined to caves. *Hickmanoxyomma tasmanicum* has surface populations at Scottsdale, Weldborough Pass and Lottah, in addition to an isolated cave population at Flowery Gully. The latter population may be considered vulnerable due to clearance of forest from around the cave. The most highly troglomorphic species occur at Precipitous Bluff and Mount Anne.

Hickmanoxyomma has been recorded from 14 karst areas but appears to be absent from the Junee-Florentine and Mount Ronald Cross karst areas, where it is replaced by troglobitic *Nuncioides* spp.

Another important group of cave dwelling harvestmen is currently under revision (Hunt & Hickman, in press); this group includes four nominal surface species in Tasmania (Hickman 1958). It comprises two sub-groupings, one with affinities to the surface species *Lomanella raniceps* and *L. atrolutea*, the other with affinities to the surface species *L. parva* and *L. exigua*.

The "*raniceps - atrolutea*" group occurs on the surface from New South Wales to Tasmania. The only cave records are from Western Tasmania: Franklin River, Andrew River, Bubs Hill, Nicholls Range and Mount Cripps Caves.

The "*parva - exigua*" group occurs on the surface in southern and central western Tasmania. The first troglobitic species was found at Hastings (Hunt 1972a) but new species have subsequently been recorded from caves at Ida Bay, Weld River and Precipitous Bluff. The Precipitous Bluff species is the world's second blind cave species in the family Triaenonychidae.

The *Lomanella* group of harvestmen is very interesting as is throws light on sub-family classification of the Triaenonychidae (Hunt & Hickman, in press).

Mestonia ?acris is recorded from the Nelson River karst area. The genus also includes a troglobitic new species at Precipitous Bluff, a possibly troglomorphic form at Loongana, plus material of undetermined status from the Franklin River.

Notonuncia sp. occurs in pseudokarst caves formed in dolerite fissures, at 1000m altitude on Mount Wellington. This material is highly troglomorphic (Hunt pers. comm.).

Species in the genus *Calliuncus* include litter dwelling types with reduced eyes, and even anophthalmic types (Hunt pers. comm.). *Calliuncus* sp. found in pseudokarst caves on Mount Wellington is probably a litter dwelling species. However, a cave adapted species is known from Margaret River in Western Australia (Hunt 1972b).

Glyptobunus is a common genus in northern and western karst areas including Redpa, Eugenana, Bubs Hill, Franklin River, Mole Creek and Gunns Plains. The Gunns Plains *Glyptobunus* sp. is possibly a troglobite (Hunt pers. comm.).

Hickmanoxyomma has not been recorded from karst areas in the far north-west of Tasmania, but *Nucina* sp. is recorded from Montagu and Redpa in this region. The epigean *N. dispar* is recorded from Kubla Khan (MC1).

The genus *Hickmanoxyomma* is closely related to *Paranuncia* and *Odontonuncia,* and the mainland genera *Equitius* and *Holonuncia* (Hunt 1985, 1990). The latter two genera are recorded from cave and epigean habitats (Hunt 1985, in press). *Holonuncia* includes troglobitic species (Hunt in press). *Paranuncia gigantea* is an endemic forest dwelling species regularly found immediately inside caves. It has been recorded from the following karst areas in western and northern Tasmania: Franklin River, Mount Ronald Cross, Loongana, Gray and Mole Creek.

The only cave record for *Leionuncia* comes from a single specimen labelled "Ida Bay Caves" It may be a faded specimen of *L. levis* collected on or near the surface (Hunt pers. comm.)

There is a rich fauna of cavernicolous triaenonychids in north American caves (Briggs 1974), New Zealand caves (Forster 1965), and at least one blind troglobitic species is known from Argentina (Maury 1988).

Distribution Records for *Hickmanoxyomma* spp. (from Hunt 1990)

***cavaticum* species group**

***Hickmanoxyomma cavaticum* (Tb)**

Hastings: King George V Cave (H-x6), Trafalgar Pot (H207), Waterloo Swallet (H-x4)

Ida Bay: Mystery Creek Cave (IB10), Exit Cave (IB14), Loons Cave (IB2), March Fly Pot (IB46), Revelation Cave (IB1), Arthurs Folly Cave (IB110), Cyclops Pot (IB57), Hobbit Hole (IB15), Little Grunt (IB23), Bradley Chestermans Cave (IB4), IB90, IB91, IB94, IB96, IB97, IB 98, IB99, IB100, IB101, IB104, IB117, IB118, IB125, IB132, IB211 plus other caves (ref. Eberhard 1990a)

North Lune: Spider Den (NL3)

***Hickmanoxyomma goedei* (Tb)**

Nicholls Range: Bill Nielson (Rotuli) Cave (NR1) and other caves (ref. Eberhard 1987a)

Scotts Peak: Huon Cave (SP1)

***Hickmanoxyomma clarkei* (Tb)**

Cracroft: Judds Cavern (C1), Matchlight Cavern (C2)

Precipitous Bluff: Bauhaus (PB6), Gaping Grin (PB22), Xymox (PB7)

***Hickmanoxyomma eberhardi* (Tb)**

Mount Anne: Col-In-Cavern (MA1), Annakananda (MA4), Deep Thought (MA10), Meltwater Pot (MA20), MA14

***Hickmanoxyomma* spp. n.**

Andrew River: Cave 1 (LA-x1)

Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)

Franklin River: Proina Cave (F51), Gahnia Cave (F74)

Vanishing Falls: Salisbury River Cave, Waterfall Spring Cave, Predator Pot

***tasmanicum* species group**
***Hickmanoxyomma tasmanicum* (Tp)**
Flowery Gully: Flowery Gully Cave (FG201)
North-east Tasmania: granite cave at Scottsdale, mine adit at Lottah and surface at Weldborough Pass (ref. Hunt 1990)
***Hickmanoxyomma gibbergunyar* (Tb)**
Mole Creek: Baldocks Cave (MC32), ?Kubla Khan (MC1), Honeycomb Cave (MC107) (MC84), Wet Cave (MC144), Herberts Pot (MC202), Westmoreland Cave (MC-x64), Cow Cave-Pyramid Cave link (MC46)

***cristatum* species group**
***Hickmanoxyomma cristatum* (Tb)**
Precipitous Bluff: Quetzalcoatl Conduit (PB3), Cueva Blanca (PB4), Damper Cave (PB1), Bauhaus (PB6)

Distribution Records for *Lomanella* new species (Hunt & Hickman, in press)
"*raniceps - atrolutea*" species group
***Lomanella* sp. (Tp)**
Lower Andrew River: Cave 1 (LA-x1)
***Lomanella* sp. n. (Tp)**
Nicholls Range: Bill Nielson Cave (NR1)
***Lomanella* sp. n. (Tp)**
Bubs Hill: Minimoria (BH202)
***Lomanella* sp. n. (Tp)**
Mount Cripps: Philrod Cave (CR3)
***Lomanella* sp. n. (Tp)**
Franklin River: Kutikina Cave (F34)

"*parva - exigua*" species group
***Lomanella* sp. n. (Tb)**
Hastings: King George V Cave (H-x6)
***Lomanella* sp. n. (Tb)**
Ida Bay: Mystery Creek Cave (IB10), Bradley Chestermans Cave (IB4), Straw Cave (IB91)
***Lomanella* sp. n. (Tb)**
Upper Weld River: Weld River Arch
***Lomanella* sp. n. (Tb)**
Precipitous Bluff: Bauhaus (PB6), Cueva Blanca (PB4)

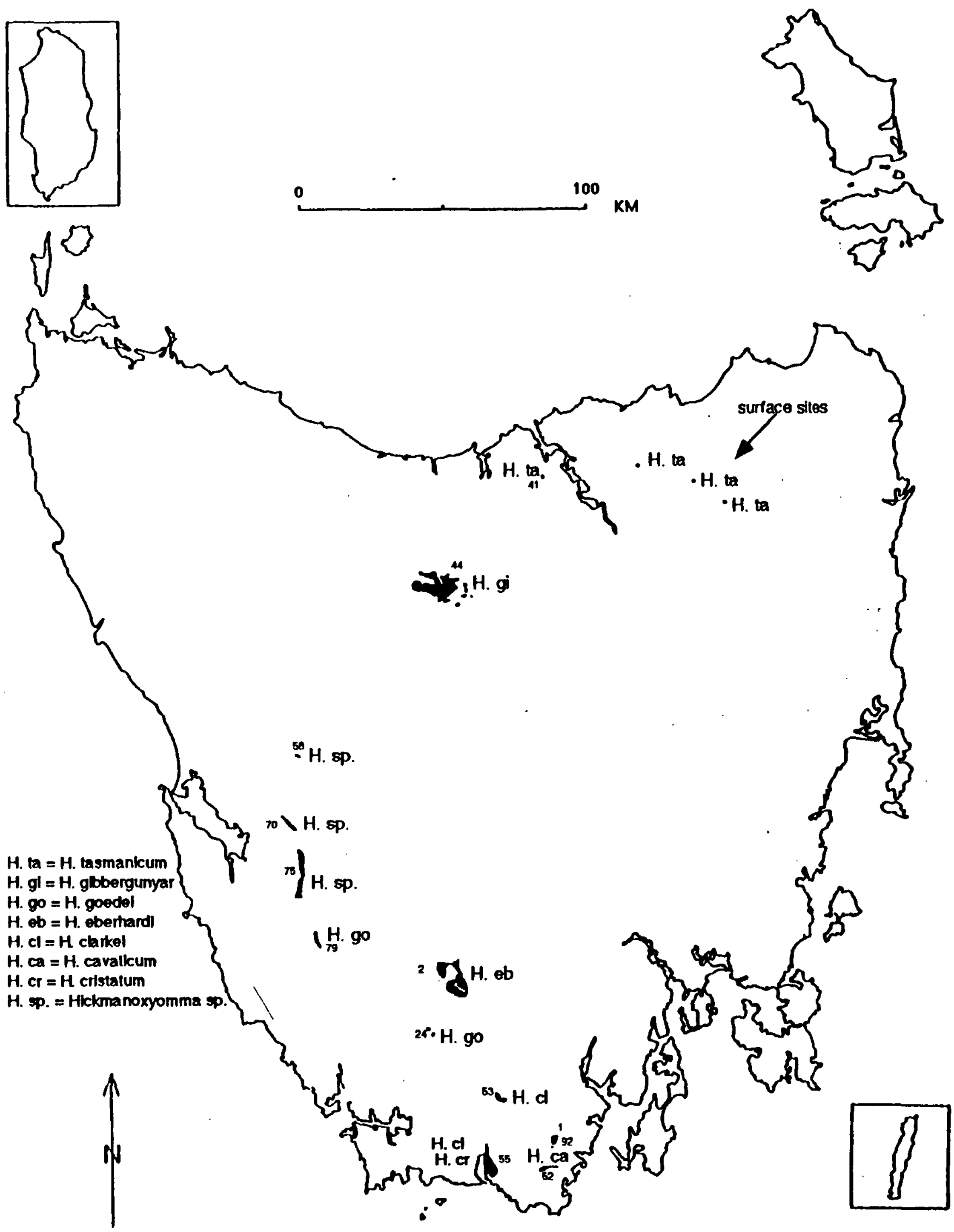


Figure 2. Distribution records for harvestmen in the genus *Hickmanoxyomma*.

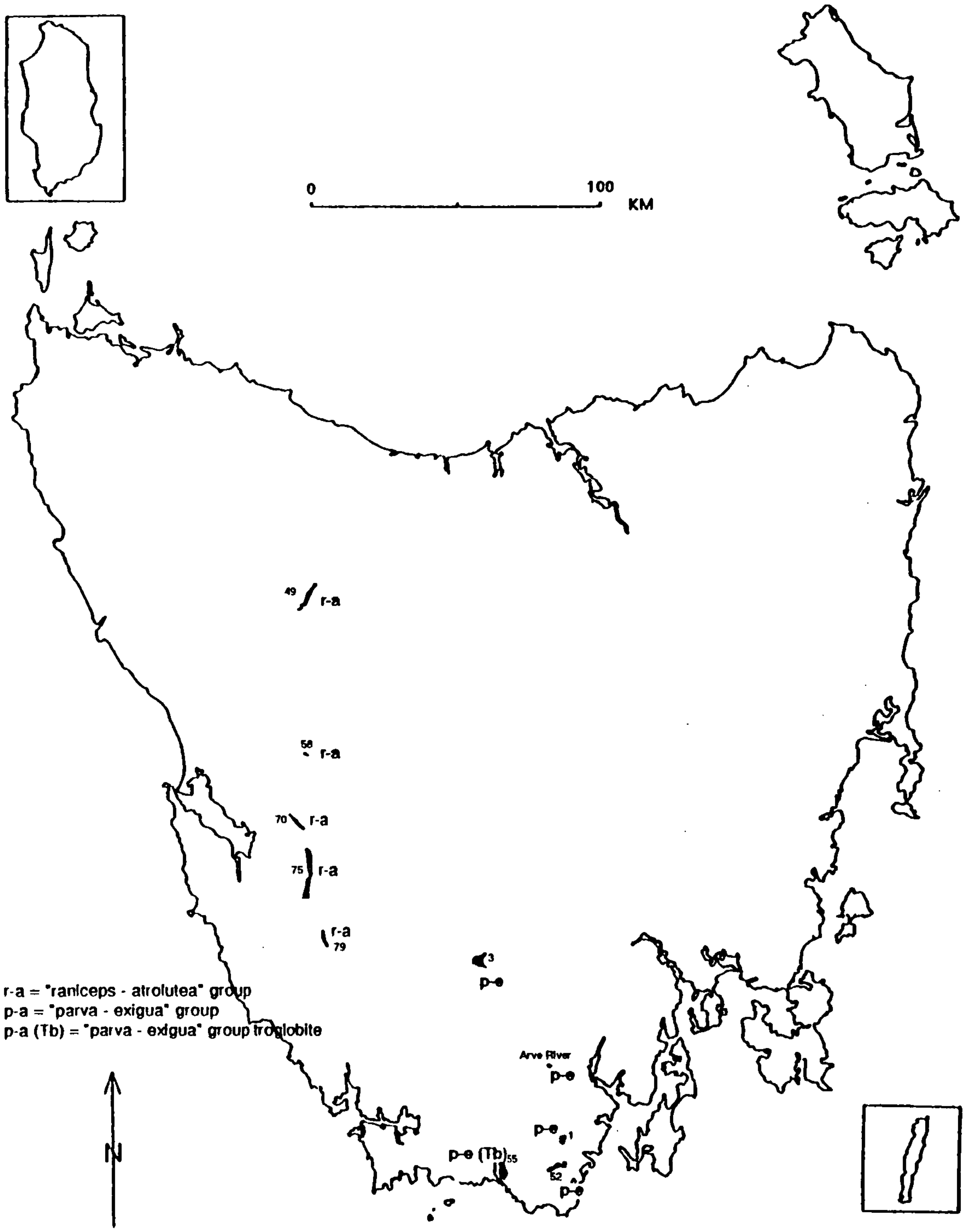


Figure 3. Cave distribution records for the harvestman *Lomanella* n. sp. (Hunt & Hickman in prep.). Arve River is a surface site.

Distribution Records for *Calliuncus* spp.
Acheron River: surface litter (Gray 1988)
Bubs Hill: surface litter (G. Hunt pers. comm.)
Franklin River: surface litter (Gray 1988)
Hastings: surface litter at entrance of King George V Cave (H-x6) (G. Hunt pers. comm.)
Mount Wellington: Cave 2 (MW-x2)
Nelson River: surface litter (Gray 1988)

Distribution Records for other triaenonychid genera (determinations by G. Hunt and J. Hickman)
***Nuncioides ?infrequens* (Tp)**
Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)
***Nuncioides ?dysmicus* (Tp)**
Bubs Hill: cave (BH16) (Clarke 1989a)
***Nuncioides* sp. (Tp)**
Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)
***Nuncioides* sp. (Tb)**
Mount Ronald Cross: Capricorn Cave (MR204), Scoparia Cave (MR-x1)
***Nuncioides* sp. (Tb)**
Junee-Florentine: Khazad-Dum (JF4), Cauldron Pot (JF2)
Risbys Basin: Ray Bender's Cave
***Mestonia ?acris* (Tp)**
Nelson River: Central Cave (N-x2)
***Mestonia* sp. n. (Tb)**
Precipitous Bluff: Tree Root Cave (PB33)
***Mestonia* sp. n. (Tb?)**
Loongana: Mostyn Hardy Cave (L4)
***Notonuncia* sp. n. (Tb)**
Mount Wellington: Cave 2 (WE-x2)
***Glyptobunus ?signatus* (Tp)**
Mole Creek: Kubla Khan (MC1)
***Glyptobunus ?* sp. n. (Tp)**
Mole Creek: Kubla Khan (MC1)
***Glyptobunus* sp. n. (Tb)**
Gunns Plains: Gunns Plains Tourist Cave (GP1)
***Glyptobunus* sp. (Tb?)**
Redpa: Glue Passage Cave (R202)
***Glyptobunus* sp. or spp. (Tp)**
Bubs Hill: 1935 Cave (BH4)
Eugenana: Sherrils Cave (E201)
Franklin River: Gahnia Cave (F74), Kutikina Cave (F34)

***Nucina dispar* (Tp)**
Mole Creek: Kubla Khan (MC1)
***Nucina* sp. or spp. (Tp)**
Montagu: Main Cave (MU201), MU203
Redpa: Glue Passage Cave (R202)
Paranuncia gigantea
Franklin River: Kutikina Cave (F34), surface
Mole Creek: Scotts Cave (MC52), Croesus Cave (MC13)
Loongana: Leven Cave (L3), Mostyn Hardy Cave (L4)
Montagu: cave (MU203), surface
Mount Ronald Cross: Capricorn Cave (MR204)
***Phoxobunus* sp.**
Bubs Hill: Minimoria (BH202) (Clarke 1989a)

Order Pseudoscorpionida

Pseudoscorpions may be found associated with wood and organic litter or underneath stones, usually in damp places. Their distribution extends from the twilight zone to the deep cave zone. They can be found on bedrock or calcite surfaces and sediment banks, particularly near watercourses, and in association with animal bones, tree roots and colonies of anapid spiders.

Troglobitic pseudoscorpions appear to be highly specialized to exploit scarce food resources and they are morphologically strongly modified for cave existence. Troglomorphies include reduction of pigment, reduction or loss of eyes, and lengthening of appendages.

With the exception of a single record of an undescribed species of *Protogarypinus* (Olpiidae) (M. Harvey pers. comm.) from Mystery Creek Cave (IB10), Tasmania's cavernicolous pseudoscorpions belong to the family Chthoniidae. Two genera are known, *Austrochthonius* and *Pseudotyrannochthonius*. *Austrochthonius australis* is recorded from IB10. This species occupies a wide variety of habitats and occurs in Western Australia, Victoria, New South Wales and Tasmania (Beier 1966). The genus also occurs in southern South America.

The dominant cavernicolous genus in Tasmania is *Pseudotyrannochthonius*. Dartnall (1970) described the troglobitic *Pseudotyrannochthonius typhlus* from caves at Mole Creek, and the troglophilic *P. tasmanicus* from Hastings. Dartnall notes that both these species appear to be most closely related to *P. jonesi* (Chamberlin), a cave dwelling species from New South Wales. All are large forms. There are 10 described species of *Pseudotyrannochthonius* occurring in Australia (Harvey 1981) and at least six of them are known only from caves (Beier 1966, 1967, 1968a, 1968b, 1971). Goede (1974) reports an undescribed species

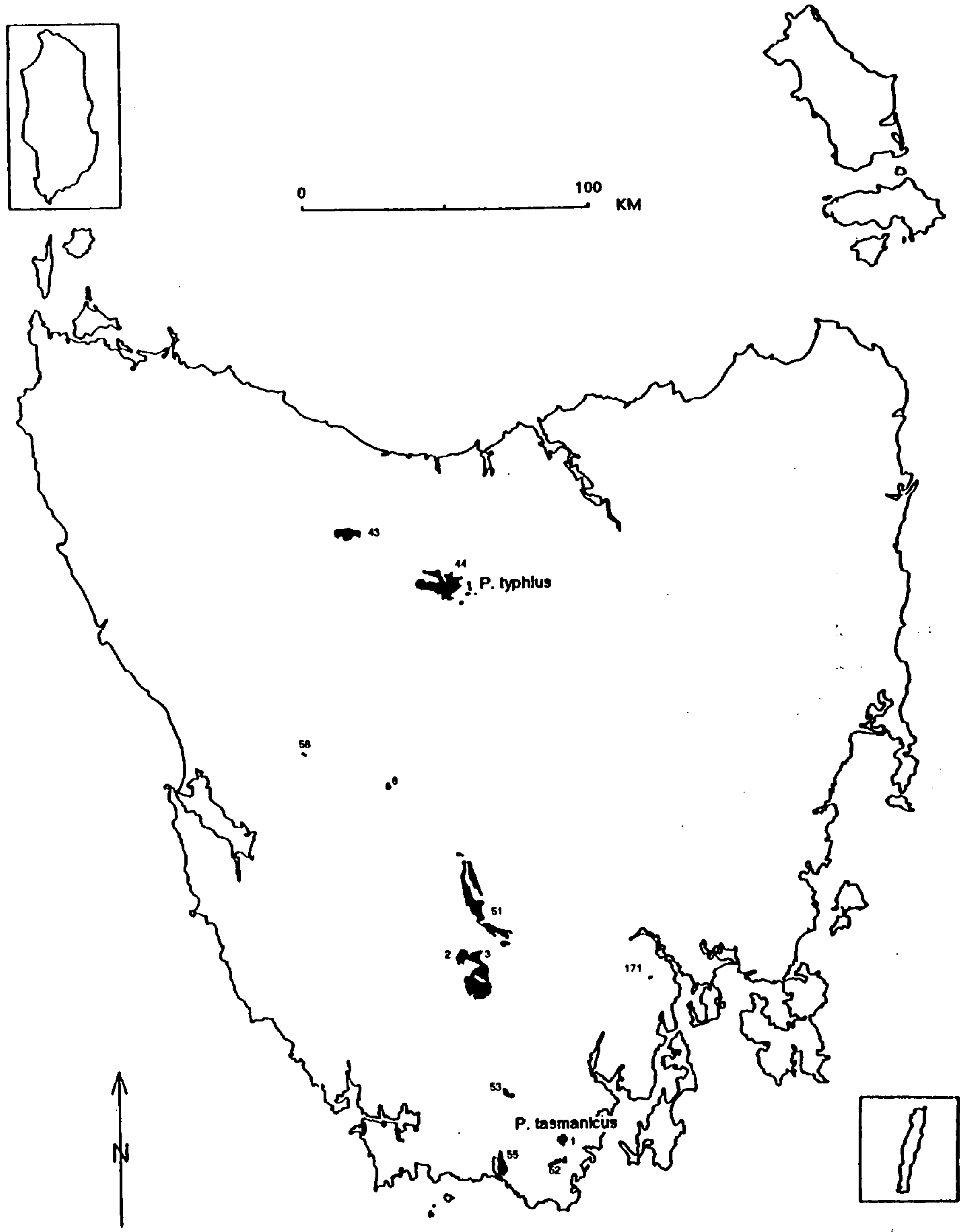


Figure 4. Distribution records for pseudoscorpions in the genus *Pseudotyrranochthonius*. Records of *P. typhlus* and *P. tasmanicus* are shown; all other records refer to unidentified *Pseudotyrranochthonius* spp.

of *Pseudotyrannochthonius* from the Florentine Valley (JF6) and our investigations identified a further 10 karst areas where the genus is known to occur. Some of this material closely resembles *P. typhlus* or the epigean species *P. tasmanicus* and *P. solitarius* (Hoff) (M. Harvey pers. comm.).

Species in the genus *Pseudotyrannochthonius* show relict distribution patterns, and the genus shows Gondwanan affinities, being represented elsewhere by several species in Chile (Beier 1966).

The Chthoniidae is a large family of world-wide distribution and a high percentage of the known troglophilic and troglobitic pseudoscorpions belong to this family. They are an important group of cavernicoles in both Europe and North America. Troglobitic pseudoscorpions occur on mainland Australia.

Pseudoscorpions are usually very rare in a given cave and many of our records are based on single specimens. Likewise, Holsinger & Culver (1988) note that troglobitic pseudoscorpions in North American caves are frequently rare and extremely localised endemics, generally recorded from single caves only.

Some of the material listed below was identified by M. Harvey.

Distribution Records for Pseudoscorpions

***Pseudotyrannochthonius typhlus* (Tb)**

Mole Creek: Georgies Hall Cave (MC201) (type locality), Baldocks Cave (MC32) (Dartnall 1970)

***Pseudotyrannochthonius tasmanicus* (Tp)**

Hastings: King George V Cave (H-x6) (type locality) (Dartnall 1970)

***Pseudotyrannochthonius* sp nov. (near *P. tasmanicus*) (Tb)**

Mount Anne: Deep Thought (MA10), Meltwater Pot (MA20), Col-In-Cavern (MA1)

***Pseudotyrannochthonius* sp. nov. (Tb?)**

Junee-Florentine: Cashions Creek Cave (JF6) (Goede 1974)

***Pseudotyrannochthonius* sp nov. (near *P. solitarius*) (Tp)**

Upper Weld River: Keyhole Cavern (UW)

***Pseudotyrannochthonius* sp. nov (near *P. typhlus*) (Tb)**

Bubs Hill: Main Drain (BH8), Thylacine Lair (BH203) (Clarke 1989a)

***Pseudotyrannochthonius* sp. nov. (near *P. solitarius*) (Tp)**

Bubs Hill: cave BH5 (Clarke 1989a)

***Pseudotyrannochthonius* sp. nov. (near *P. tasmanicus*) (Tb)**

Ida Bay: March Fly Pot (IB46), Salt and Pepper (IB99), Giotto Pot (IB104)

***Pseudotyrannochthonius* sp. (Tp or Acc)**

Mount Wellington: Cave 1 (WE-x1), Cave 2 (WE-x2)

***Pseudotyrannochthonius* sp. (near *P. typhlus*?) (Tb)**
Junee-Florentine: cave JF208
***Pseudotyrannochthonius* sp. (Tb)**
Precipitous Bluff: Quetzalcoatl Conduit (PB12)
***Pseudotyrannochthonius* sp. (near *P. typhlus*) (Tb)**
Precipitous Bluff: Tree Root Cave (PB33)
***Pseudotyrannochthonius* sp. (Tp)**
Loongana: Mostyn Hardy Cave (L4)
***Pseudotyrannochthonius* sp. (near *P. tasmanicus*) (Tp)**
Mount Ronald Cross: Capricorn Cave (MR204)
***Pseudotyrannochthonius* sp. (Tb?)**
Mole Creek: Kellys Pot (MC207)
***Pseudotyrannochthonius* sp. or spp. (Tb)**
Mole Creek: Kubla Khan (MC1), Genghis Khan (MC39), Little Trimmer Cave (MC38)
***Pseudotyrannochthonius* sp. (Tb)**
Cracroft: Matchlight Cavern (C2)
***Pseudotyrannochthonius* sp. (Tb)**
Vanishing Falls: Salisbury River Cave, Predator Pot
Chthoniidae sp. indet.
Bubs Hill: 1935 Cave (BH4)
Chthoniidae sp. indet. (Tb?)
Loongana: Mostyn Hardy Cave (L4)
Chthoniidae sp. indet. (Tb?)
Ida Bay: Arthurs Folly Cave (IB110)
***Austrochthonius australis* Hoff (Tp)**
Ida Bay: Entrance Cave (IB10)
***Protogarypinus* sp. nov. (F. Olpiidae) (Tp)**
Ida Bay: Entrance Cave (IB10)

Order Araneae

Tasmanian caves hold a diverse and interesting spider fauna. The following families have been recorded: Amaurobiidae, Anapidae, Araneidae Austrochilidae, Clubionidae, Cycloctenidae, Hahniidae, Holarchaeidae, Linyphiidae, Malkaridae, Metidae, Micropholcommatidae, Mimetidae, Mysmenidae, Orsolobidae, Salticidae, Stiphidiidae, Synotaxidae, Textricellidae, Theridiidae, Theridiosomatidae (Clarke 1989a, 1990; Eberhard 1988a; Gray 1988 & pers. comm.). Groups such as Araneidae, Clubionidae, Linyphiidae, Mimetidae, Orsolobidae and Salticidae contain species which are mostly recorded as accidental cavernicoles. The most important groups from a biospeleological point of view are the Amaurobiidae, Anapidae, Austrochilidae, Micropholcommatidae, Mysmenidae, Synotaxidae and Theridiidae. The identifications given below were provided by Dr M. Gray.

Amaurobiidae

The Amaurobiidae are represented in Tasmanian caves by a complex of new genera and species closely related to *Rubrius milvinus* Simon, which is a vagrant hunter in rainforest (Hickman 1967). The new genus is widely distributed and often locally abundant. Its distribution extends from the twilight zone to the deep cave zone. It does not spin a web but wanders widely across most habitat and substrate types including sediment banks, bedrock and calcite surfaces, logs and litter deposits, pools and streamways. It is likely to be the dominant terrestrial predator in the deep cave zone. The species appears to be troglobitic as juveniles are clearly depigmented and with some degree of eye reduction (M. Gray pers. comm.).

Distribution Records for Amaurobiidae Gen. *et* spp. nov.

Acheron River: Cardia Cave, Cave 1
Bubs Hill: BH4 and other caves (ref. Clarke 1989a)
Cracroft: Judds Cavern (C1)
Eugenana: Sherrils Cave (E201)
Franklin River: Gahnia Cave (F74), Kutikina Cave (F34), Proina Cave (F51)
Gray: Rum Pot (G-x3)
Gunns Plains: Gunns Plains Tourist Cave (GP1)
Hastings: King George V Cave (H-x6), Wolfe Hole (H-x8)
Ida Bay: Hobbit Hole (IB15) plus other caves (ref. Eberhard 1990a)
Junee-Florentine: Cauldron Pot (JF2), Growling Swallet (JF36), Khazad Dum (JF4), Serendipity (JF344), Rift Cave (JF34), Burning Down The House (JF402), cave (JF208), Gormenghast (JF35), Troll Hole (JF-x1), "Wherrets" Cave (JF-x6)
Loongana: Leven Cave (L3), Mostyn Hardy Cave (L4), Swallownest Cave (L5)
Lower Maxwell River: "Cricket" Cave (LM-x1)
Mole Creek: Kubla Khan (MC1), Little Trimmer Cave (MC38), Kellys Pot (MC207)
Mount Ronald Cross: Capricorn Cave (MR204)
Mount Wellington: Cave 1 (MW-x1), Cave 2 (MW-x2)
Nicholls Range: Bill Nielson Cave (NR1)
North Lune: Spider Den (NL3)
Precipitous Bluff: Damper Cave (PB1), Bauhaus (PB6), Quetzalcoatl Conduit (PB3)
Redpa: Cow Cave (R204), Glue Passage Cave (R202)
Risbys Basin: Ray Bender's Cave
Trowutta: surface
Upper Weld River: Keyhole Cavern (UW)

Vanishing Falls: Salisbury River Cave

Austrochilidae

The best known species is the Tasmanian Cave Spider, *Hickmania troglodytes.* This large spider, in a monospecific endemic genus, is common in virtually all Tasmanian caves. It dwells in the entrance and twilight zones, and some distance into the dark zone, but never a great distance from the entrance. It also occurs in suitably cool and dark surface habitats, such as hollow logs and tree stumps, hollows in rocks, mine shafts and occasionally suburban dwellings (Hickman 1967). In caves, the spider preys upon cave crickets in the genus *Micropathus,* but it will take a variety of prey. *H. troglodytes* is of considerable systematic and zoogeographic interest because its closest relatives live in Chile and Argentina. These species are members of the superfamily Austrochiloidea, which together with members of the Hypochiloidea (from China and the USA), are the most primitive of the araneomorphs. These superfamilies are reviewed by Forster *et al.* (1988). Cave adaptation and life history of *H. troglodytes* is the subject of a thesis by Doran (1991)

H. troglodytes was observed commonly in caves of all karst areas sampled, except for two areas where no sightings were made, the Acheron River and the North East Ridge of Mount Anne (Eberhard 1987a; 1988a). The reason for their absence on Mount Anne may be related to the strong air currents in the caves here, which would destroy a spider's web. However, further searching in caves without strong air currents, may well reveal the species presence. On the Acheron River, another spider species was found in the habitats normally occupied by *H. troglodytes* (M. Gray pers. comm.).

Synotaxidae

The genus *Tupua* is endemic to Tasmania; three species have been found in caves, and at least one is probably an obligate cave dweller (Forster *et al.* 1990). It belongs to the family Synotaxidae with a southern hemisphere distribution. *Tupua* spp. spin fine sheet webs. Troglophilic species such as *Tupua bisetosa* may occur abundantly in the entrance, twilight and transition zones, often associated with logs and litter deposits. Troglobitic species such as *Tupua troglodytes* are found in the twilight to deep cave zone, where sometimes numerous individual webs are clustered in close proximity to each other. The webs may be slung in floor crevices or calcite formations. *T. troglodytes* is known from Precipitous Bluff, the Franklin River and the Florentine Valley. The species has reduced eyes and is depigmented whereas *T. cavernicola* has pale colouration and is known from the Mount Anne and Cracroft karst areas. Further undescribed or unidentified material is known from other karst areas.

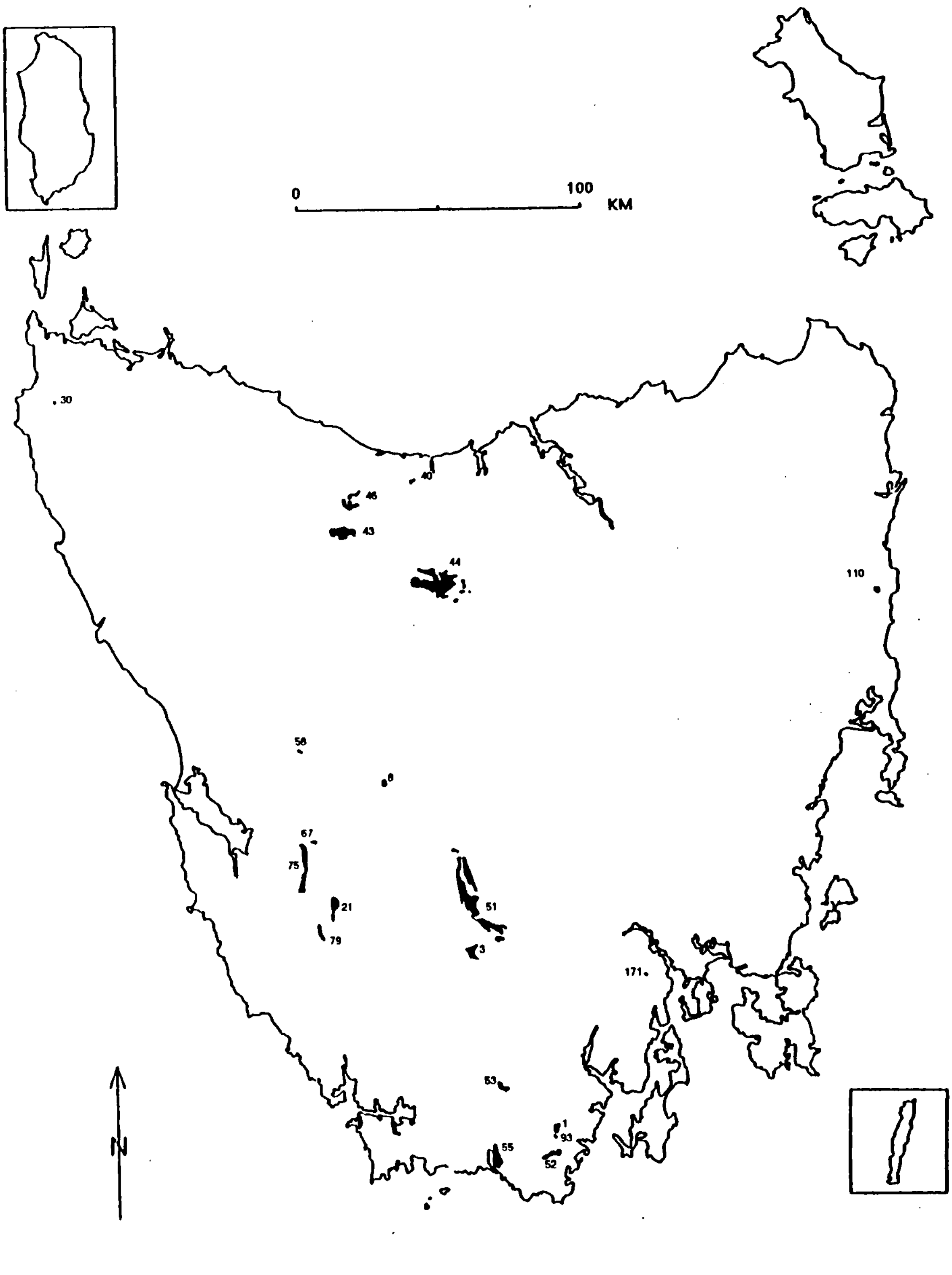


Figure 5. Distribution records of undescribed genera and species of spiders in the Family Amaurobiidae.

Distribution Records for *Tupua* spp.

***Tupua troglodytes* (Tb)**
Florentine Valley: Gelignite Pot (JF391), Asteroid Pot (JF366), cave JF395
Franklin River: Gahnia cave (F74)
Precipitous Bluff: Cueva Blanca (PB4)

***Tupua cavernicola* (Tb)**
Cracroft: Judds Cavern (C1)
Mount Anne: Col-In-Cavern (MA1), Deep Thought (MA10)

***Tupua bisetosa* (Tp)**
Hastings: King George V Cave (H-x6) (Forster *et al.* 1990)
Mole Creek: Kubla Khan (MC1)

***Tupua ?raveni* (or *cavernicola*)**
North Lune: Spider Den (NL3)

***Tupua* spp. (near *bisetosa*) (Tp & Tb?)**
Mount Wellington: Cave 1 (WE-x1), Cave 2 (WE-x2)

***Tupua* spp. indet.**
Acheron River: Cardia Cave (AR-x2) (TpII)
Franklin River: Kutikina Cave (F34) (TpII)
Ida Bay: March Fly Pot (IB46), Revelation Cave (IB1), Little Grunt (IB23), IB51, IB90, IB91, IB93, IB94, IB96, IB97, IB 98, IB99, IB100, IB101, IB117, IB118, IB125, IB132, IB211 plus other caves (ref. Eberhard 1990a) (Tp)
Loongana: Mostyn Hardy Cave (L4)
Lower Andrew River: Cave 1 (LA-x1) (TpII)
North Lune: Spider Den (NL3)
Precipitous Bluff: Bauhaus (PB6) (Tp?)

Theridiidae

The principal theridiid genus in Tasmanian caves is *Icona,* recorded from 20 karst areas to date. The spider spins a fine sheet web on walls, between cracks in formations or under wood. It is usually found in the transition zone or beyond, and individuals are generally in low abundance. The genus is distributed in caves across southern Australia, but otherwise it is known only from the subantarctic islands of New Zealand (Gray 1973a). The Australian species are variably troglomorphic, ranging from fully eyed and only slightly depigmented species to blind, pale troglobites (Gray 1988). Both troglophilic and troglobitic forms are represented in Tasmania, as well as the only known epigean populations from rainforest in the Franklin River valley. Troglobites occur at Eugenana, Flowery Gully, Franklin River, Gray, Gunns Plains, Ida Bay, Loongana, Lower Andrew River, Mole Creek, Montagu and Precipitous Bluff. Gray (1988) suggests that species in the genus *Icona* are a strongly hygrophilic group which has survived mainland drying only in cave habitats, but has persisted in stable temperate forest habitats in Tasmania.

Distribution Records for *Icona* spp.
Bubs Hill: caves BH5, BH8, BH19 (Clarke 1989a) (Tp)
Eugenana: Sherrils Cave (E201) (Tb)
Flowery Gully: Flowery Gully Cave (FG201)
Franklin River: Kutikina Cave (F34) (Tb)
Gordon-Sprent: Cave 4 (GS-x4) (Tp)
Gray: Rum Pot (G-x3), G-x2
Gunns Plains: Gunns Plains Tourist Cave (GP1), Weerona Cave (GP2) (Tb)
Hastings: King George V Cave (H-x6)
Ida Bay: Mystery Creek Cave (IB10) (Tp); Arthurs Folly (IB110), March Fly Pot (IB46) (Tb)
Junee-Florentine: Khazad Dum (JF4)
Loongana: Mostyn Hardy Cave (L4), Leven Cave (L3), Swallownest Cave (L5) (Tb)
Lower Andrew River: Cave 2 (LA-x2) (Tb)
Mole Creek: Kubla Khan (MC1) (Tb & Tp), Bayards Rising Cave (MC-x1)
Montagu: Main Cave (MU201) (Tb)
Mount Wellington: Cave 1 (WE-x1)
Nelson River: Central Cave (N-x2)
Nicholls Range: Bill Nielson cave (NR1)
Precipitous Bluff: Damper Cave (PB1), Quetzalcoatl Conduit (PB3) (Tb)
Redpa: Glue Passage Cave (R202), Cave 1 (R-x1)
Risbys Basin: Ray Bender's Cave
Vanishing Falls: Salisbury River Cave

Another theridiid genus recorded is *Achaearanea,* including *Achaearanea* spp. from Ile du Golfe (IG-x1) and Bubs Hill (BH5), and *A. extrilidum* from Gunns Plains (GP1 & GP2). There is a single record of *Phoroncidia* sp. from BH5. These species are adventitious cavernicoles found in the entrance and twilight zones. Unidentified theridiids are recorded from Eugenana (E201) and Flowery Gully (FG201).

Mysmenidae, Anapidae, Micropholcommatidae and Holarchaeidae
Tasmanian caves hold a rich fauna of tiny, hygrophilic spiders in the families Mysmenidae, Anapidae, Micropholcommatidae and Holarchaeidae. Troglobites are known in all of these groups except the Mysmenidae and Holarchaeidae. Only the Anapidae and Mysmenidae are known to occur outside Australia and New Zealand (Gray 1988).

A mysmenid spider taken from Kutikina Cave (F34) is attributable to the genus *Trogloneta.* The Tasmanian *Trogloneta* may be a distributional relict, dating back

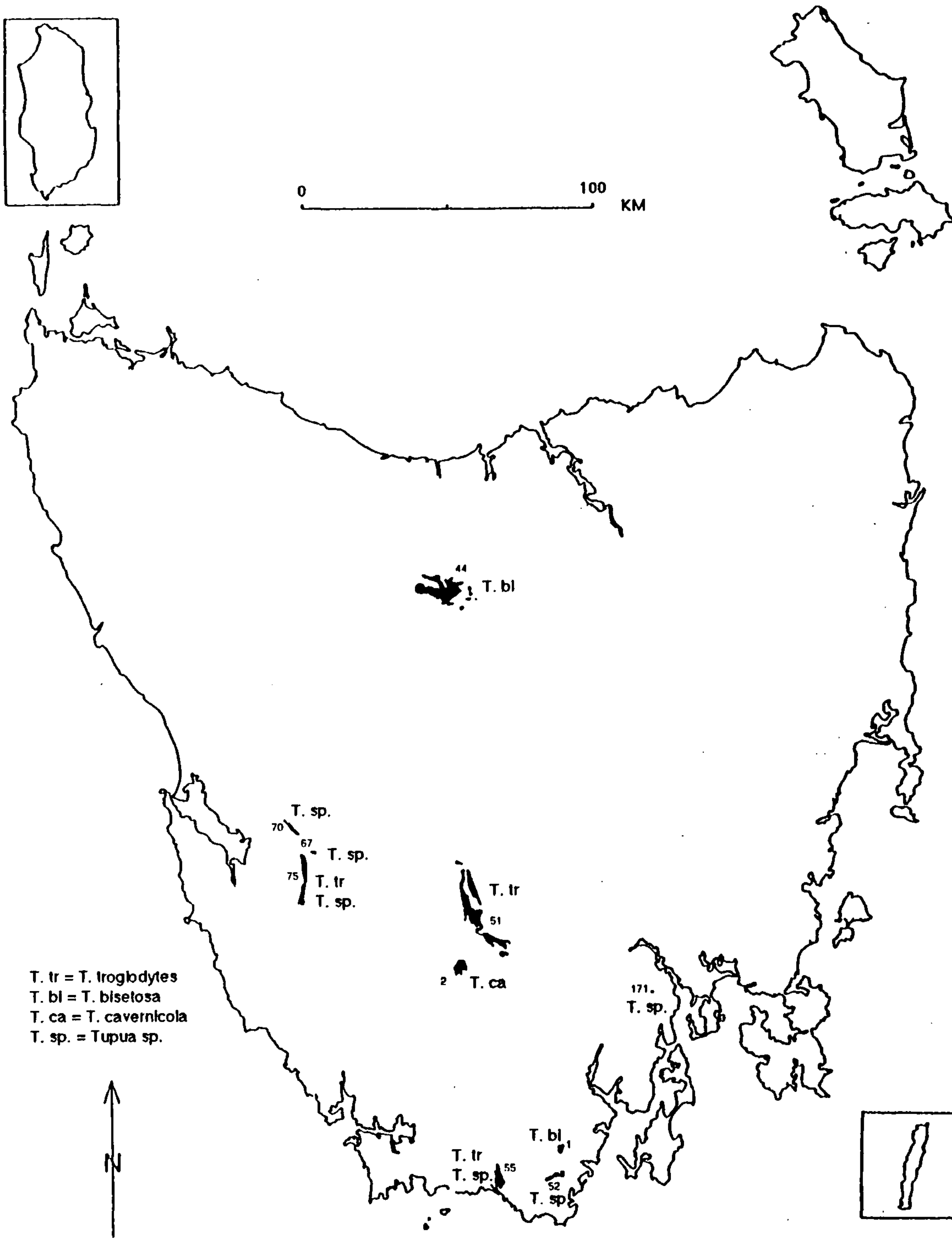


Figure 6. Distribution records for spiders in the synotaxid genus *Tupua*.

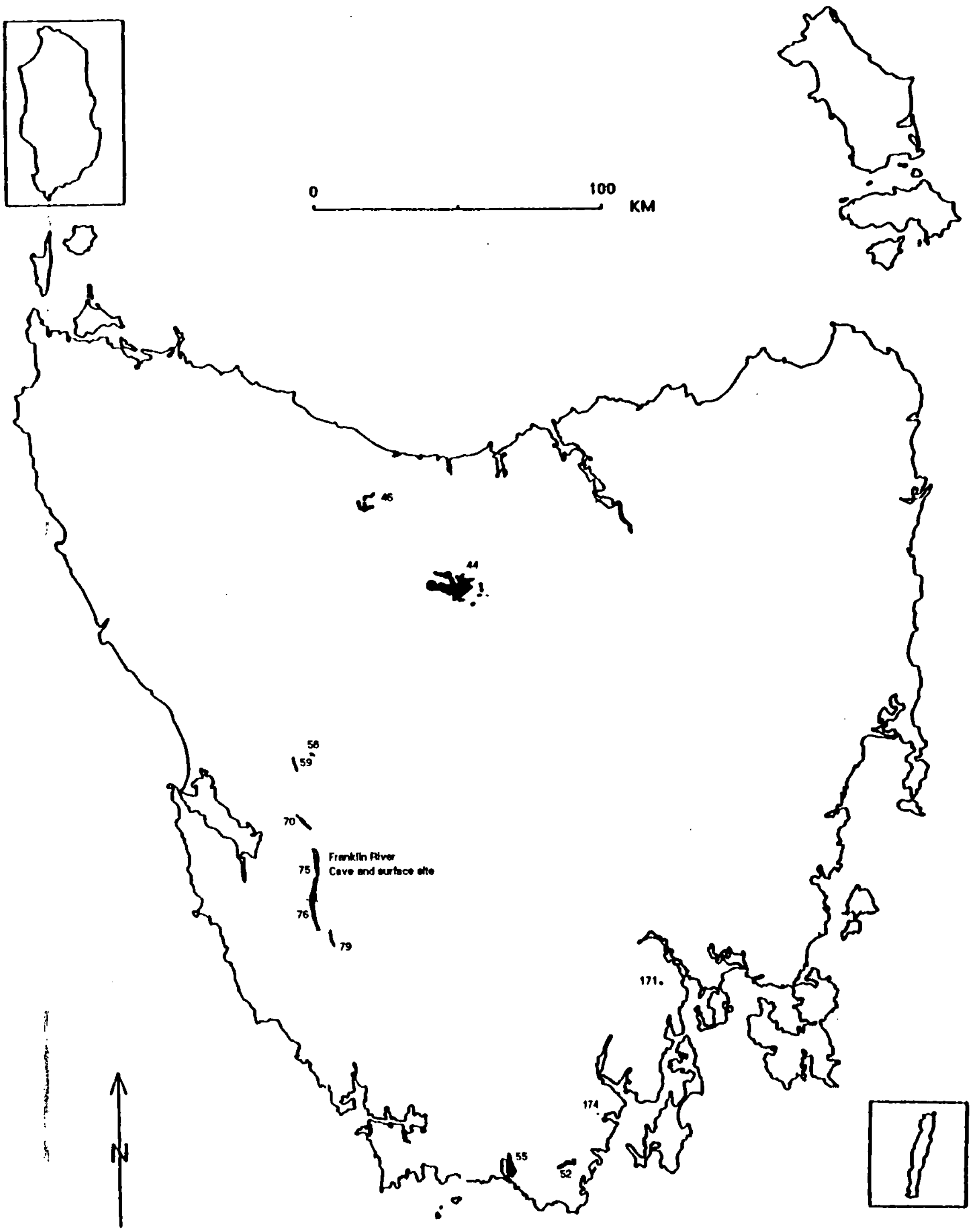


Figure 7. Distribution records for theridiid spiders in the genus *Icona*.

at least to the breakup of Pangaea, which establishes an intriguing link between northern and southern faunas (Gray 1988). Other mysmenid genera recorded include *Mysmena* and *Acrobleps,* the latter recently transferred from the family Anapidae (Platnick & Forster 1989). Unidentified mysmenid material comes from IB129, plus a new genus and species of troglobite from MC38.

Distribution Records for Mysmenidae

Acrobleps hygrophilus

Lower Andrew River: Cave 1 (LA-x1) (Tp)

***Acrobleps* sp.**

Franklin River: Kutikina Cave (F34) (TpII), Gahnia Cave (F74)

Junee-Florentine: Khazad Dum (JF4), Gormenghast (JF35)

Mount Ronald Cross: Capricorn Cave (MR204)

***Mysmena* sp.**

Franklin River: Kutikina Cave (F34)

Mysmenidae Gen. et sp. n.

Mole Creek: Genghis Khan (MC38) (Tb)

Mysmenidae sp.

Ida Bay: Great Expectations Cave (IB129)

The micropholcommatid genus *Olgania* is represented by one rare surface species *O. excavata* Hickman, plus several undescribed cave dwelling forms. Some of the cave material is highly troglomorphic, with eyes being totally absent. *Olgania* sp. live in small sheet webs slung between cracks in the walls or floor, often near a source of dripping or flowing water. They are typically found clustered together in "colonies". The troglobitic forms are generally restricted to the deep cave zone. The genus has been recorded from six Tasmanian karst areas, with troglobites at Ida Bay, Franklin River and Cracroft.

Distribution Records for *Olgania* spp.

Bubs Hill: (BH4), (BH203) (*O. excavata* Tp)

Cracroft: Judds Cavern (C1) (Tb & Tp)

Franklin River: Kutikina Cave (F34) (Tb)

Ida Bay: Loons Cave (IB2), Arthurs Folly (IB110) (Tb)

Junee-Florentine: Splash Pot (JF10)

Upper Weld River: Keyhole Cavern (Tp)

Gray (1973a) reports a troglobitic *Textricella* sp. from Loongana (L4). Cave adaptations include loss of anterior median eyes, lack of pigment and abdominal sclerotisation. *Textricella* is also known from Montagu (MU201 & MU203). A non-troglomorphic *Textricella* sp. and Micropholcommatidae sp. indet. are recorded from IB10 and Keyhole Cavern (UW) respectively. *Micropholcomma* sp. is recorded from JF10. An unidentified ?micropholcommatid is recorded from

Vanishing Falls.

The Anapidae are represented in caves by specimens tentatively assigned to the genera, *Chasmocephalon* and *Pseudanapis,* in addition to other unidentified material. *Chasmocephalon* sp. from MC1 is a troglobite. However, these two named genera have not previously been recorded from Tasmania (Forster & Platnick 1989).

Distribution Records for Anapidae
***Chasmocephalon* sp.**
Mole Creek: Kubla Khan (MC1) (Tb)
***Pseudanapis* sp. (TpII?)**
Acheron River: Cardia Cave (AR-x2)
Franklin River: Kutikina Cave (F34)
Precipitous Bluff: Bauhaus (PB6)
Anapidae spp.
Acheron River: Cardia Cave (AR-x2)
Ida Bay: Dismal Hill Pot (IB130) (Tb)

The only holarchaeid recorded from caves is *Holarchaea globosa* (Hickman) at Acheron River (AR-x1 & AR-x2) and Montagu (MU201) (Gray 1988).

Stiphidiidae
Stiphidiids are widely distributed. They are most abundant in entrance and twilight zones which remain relatively dry. They could be regarded as part of the parietal association. They spin a sombrero-shaped sheet web. *Stiphidium facetum* is an epigean species, which is common in Tasmanian and also south-east mainland caves (Gray 1973a). Other stiphidiids belong to a new genus comprising at least two species (M. Gray pers. comm.). One of these is a widely distributed troglophile whilst the other is a troglobite from Bubs Hill and the Franklin River. The new genus is related to the mainland genus *Baiami* which contains several cavernicolous species (including one highly specialised troglobite) (Gray 1973b, 1981).

Distribution Records for Stiphidiidae
***Stiphidion facetum* Simon**
Eugenana: Sherrils Cave (E201)
Flowery Gully: Flowery Gully Cave (FG201), Vanishing Cave (FG202)
Franklin River: Kutikina Cave (F34), F27
Gunns Plains: Gunns Plains Tourist Cave (GP1), Weerona Cave (GP2), surface
Loongana: Leven Cave (L3)
Mole Creek: Baldocks Cave (MC32)

Mount Ronald Cross: Scoparia Cave (MR-x1)
Mount Wellington: Cave 1 (WE-x1)
Redpa: (R202), (R204)
Trowutta: Trowutta Arch (T201)

Stiphidiidae Gen. *et* spp. n.
Acheron River: Cardia Cave (AR-x2), Cave 1 (AR-x1)
Bubs Hill: Minmoria (BH202), Thylacine Lair (BH203), BH8 (Tb)
Cheyne Range: cave (CR-x1)
Junee-Florentine: Punishment Pot (JF373), JF395
Franklin River: Kutikina Cave (F34) (Tb), Proina Cave (F51), Cave 1 (F-x1)
Gordon-Sprent: Cave 1 (GS-x1)
Mole Creek: Kubla Khan (MC1)
Montagu: (MU201)
Mount Ronald Cross: Capricorn Cave (MR204), Scoparia Cave (MR-x1)
Nicholls Range: Bill Nielson Cave (NR1)
Precipitous Bluff: Damper Cave (PB1), Quetzalcoatl Conduit (PB3)
Scotts Peak: Huon Cave (SP1)
Upper Weld River: Weld River Arch
Vanishing Falls: cave

Metidae
Another common and widely distributed group is the Metidae. At least two genera are represented, including *Meta* and '*Orsinome*'. They are troglophiles, and spin orb webs in the entrance and twilight zones, but rarely penetrate into the dark zone. *Meta* is the most common. Species in this genus occur in many northern hemisphere caves (Vandel 1965).

<u>Distribution Records for Metidae</u>
***'Orsinome'* sp. (Tp)**
Bubs Hill: Main Drain (BH8), Minimoria (BH202)
Gordon-Sprent: Cave 4 (GS-x4)
Ida Bay: Mystery Creek Cave (IB10)
Nicholls Range: Bill Nielson Cave (NR1)
***Meta* sp. (Tp)**
Acheron River: Cardia Cave (AR-x2), Cave 1 (AR-x1)
Davey River: Cavel (DV-x1), Cave 2 (DV-x2)
Franklin River: Proina Cave (F51), Gahnia Cave (F74)
Mount Ronald Cross: Capricorn Cave (MR204), Scoparia Cave (MR-x1)
Mount Wellington: Cave 1 (WE-x1), Cave 2 (WE-x2)
Nelson River: Nelson River Inflow Cave (N-x1), Central Cave (N-x2)
Precipitous Bluff: Bauhaus (PB6)

Metinae sp.
Cracroft: Judds Cavern (C1)
Ida Bay: (IB11)
Junee-Florentine: Khazad Dum (JF4), (JF5)
Montagu: surface
Scotts Peak: Huon Cave (SP1)
Trowutta: Trowutta Arch (T201)
Metidae sp.
Junee-Florentine: Punishment Pot (JF373), JF395
Mole Creek: Kellys Pot (MC207), Bayards Rising Cave (MC-x1)
Risbys Basin: Ray Bender's Cave
Vanishing Falls: caves
Metidae ?Gen. et sp. n. (Tp)
Bubs Hill: BH8, BH18, BH203
North Lune: Spider Den (NL3)

Theridiosomatidae
The Theridiosomatidae is a small family of cryptozoic, hygrophilic, orb weaving spiders distributed mainly in the northern hemisphere. Although mainly recorded from caves, specimens from New South Wales, South Australia, Western Australia and Tasmania show few signs of cave modification (Gray 1973a). The family is represented in Tasmanian caves by at least three species in the genus *Baalzebub*. They are all troglophiles. Specimens are usually found on walls in the entrance, twilight and transition zones.

<u>Distribution Records for *Baalzebub* spp.</u>
Bubs Hill: BH5
Davey River: Cave 2 (DV-x2)
Eugenana: Sherrils Cave (E201)
Flowery Gully: Flowery Gully Cave (FG201)
Franklin River: Kutikina Cave (F34), Proina Cave (F51)
Gray: Rum Pot (G-x3), G-x2
Gunns Plains: Gunns Plains Tourist Cave (GP1)
Loongana: Leven Cave (L3)
Lower Andrew River: Cave 2 (LA-x2)
Mole Creek: Kubla Khan (MC1), Croesus Cave (MC13), Genghis Khan (MC38), Bayards Rising Cave (MC-x1)
Montagu: MU201
Nicholls Range: Bill Nielson Cave (NR1)
Redpa: Cave 1 (R-x1)

Cycloctenidae

The Cycloctenidae are forest litter hunting spiders indigenous to Australia and New Zealand (Gray 1973a). The genera *Toxopsiella, Toxopsioides* and *Cycloctenus* are recorded from Tasmanian caves; the latter genus includes at least two undescribed species. They are usually found near cave entrances in the twilight zone, but have been collected in the dark zone. *Cycloctenus* spp. are also known from caves in Victoria and New South Wales (Gray 1973a).

Distribution Records for Cycloctenidae

Cycloctenus cryptophilus

Davey River: Cave 2 (DV-x2)

Franklin River: Kutikina Cave (F34), Proina Cave (F51)

Cycloctenus flavus

North Lune: Spider Den (NL3)

***Cycloctenus* spp.**

Acheron River: Cardia Cave (AR-x2), Cave 1 (AR-x1)

Bubs Hill: BH2, BH8, BH22, BH202

Gray: Rum Pot (G-x3)

Lower Maxwell River: "Cricket Cave" (LM-x1)

Mole Creek: Genghis Khan (MC38)

Mount Ronald Cross: Capricorn Cave (MR204)

Mount Wellington: Cave 2 (WE-x2)

North Lune: Spider Den (NL3)

Ranga (Flinders Island): Ranga Cave (RA-x1) (Gray 1973a)

Toxopsiella sp.

Ile du Golfe: Cave 2 (IG-x2)

Toxopsioides sp.

Flowery Gully: Flowery Gully Cave (FG201)

Mimetidae

The Mimetidae are represented by a single genus, *Australomimetus,* recorded in the entrance - twilight zone of GP1, E201, MU201, FG201 and F-x1.

Linyphiidae

The Linyphiidae are poorly represented in Tasmanian caves; unidentified linyphiids are known from MC38 and WE-x1, in addition to a troglophilic *Porrhomma* sp. from IB10. Other troglophilic linyphiids occur across southern Australia and a troglobitic form occurs at Jenolan Caves, New South Wales (Gray 1973a). The Linyphiidae are particularly common in the northern hemisphere, where the genus *Porrhomma* appears to be a 'glacial relic' of great speleological interest (Vandel 1965).

Other Families

The remaining spider families recorded from Tasmanian caves (Araneidae, Hahniidae, Clubionidae, Malkaridae, Orsolobidae and Salticidae) are all represented by species considered to be accidental cavernicoles. They are not considered further here, but some distribution records are given in Clarke (1989a, 1990).

Order Acarina

The taxonomy and ecology of cave associated acarines in Tasmania are poorly known. Both ticks and mites have been recorded. No troglobitic forms have been identified, but these do occur in other parts of the world (including terrestrial mites and aquatic hypogean acarina).

Ticks are recorded from caves which are visited by native mammals such as platypus, brushtail possum, wombat and rodents. They are often found near the nests of these mammals. Species identified include *Ixodes trichosuri* from the dark zone in Mersey Hill Cave (MC75), where the most probable host is the Brushtail Possum (*Trichosurus vulpecula*). *Ixodes ornithorhynchi,* which is a parasite of the platypus (*Ornithorhyncus anatinus*), is recorded from Exit Cave (IB14), Scotts Cave (MC52) and Croesus Cave (MC13) (Goede *et al.* 1974a, Hamilton-Smith 1967). *Aponomma auruginans* Schulze 1936 is recorded from Ranga Cave (RA-x1) on Flinders Island, where it is a common tick of wombats (Goede *et al.* 1974a).

Free-living terrestrial mites (including shield mites and pillbox mites) may be abundant in cave litter deposits. They are likely to be accidental cavernicoles, either associated with the gravity input of litter at cave entrances, or swept into caves during floods. There may be dense populations in flood litter which may survive for varying lengths of time in the dark zone. Other mites which are not accidentals occur on wood, or are found under stones or roaming on siltbanks.

One conspicuous mite in Tasmanian caves is a large bright red velvet mite in the family Trombidiidae (?*Microtrombidium* sp.). It is usually found on walls in the dark zone, or near entrances. Members of this family are generally parasitic upon arthropods as juveniles, but free-living as adults. Goede *et al.* (1974a), in recording *Microtrombidium* sp. from JF6, postulated an association with cave crickets but this has not yet been substantiated.

From Bubs Hill, Clarke (1989a) recorded six species belonging to five families. All of these were predatory species and none were confined to the hypogean environment. One of the families (Euopodidae) contains troglophiles which are widespread in European caves (Vandel 1965).

On the Australian mainland, the majority of mite species recorded are associated with bat guano or litter, and although a large number are apparently confined to the cave habitat, none appear to be fully troglobitic. Hamilton-Smith (1967), in reviewing the free-living mites from Australian caves, found systematic parallels with cave faunas in both Europe and North America, namely the Macrochelidae and Trombidiidae, both of which are recorded from Tasmanian caves. In addition to Europe and North America, cavernicolous trombiids are also known from Japan, Madagascar, the Congo and Central America.

Distribution Records for Free-Living Mites

Anystidae (*Anystis baccarum*)
Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)
Erythraeidae (*Erythrites (Erythrites)* sp.)
Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)
Hydracarina sp. indet.
Gunns Plains: Gunns Plains Tourist Cave (GP1)
(close to) Macrochelidae sp. indet.
Hastings: King George V Cave (H-x6) (Goede *et al.* 1974a)
Oribatidae sp. indet.
Hastings: King George V Cave (H-x6) (Goede *et al.* 1974a)
Oribatidae sp. indet.
Acheron River: Cave 1 (AR-x1)
Bubs Hill: Minimoria (BH202)
Franklin River: Gahnia Cave (F74)
Gray: Rum Pot (G-x3)
Junee-Florentine: Cashions Creek Cave (JF6), cave (JF208), cave (JF-x2)
Loongana: Leven Cave (L3) Lower Maxwell River: Ballawinne Cave (LM-x4)
Uropidae spp. indet.
Bubs Hill: BH5, BH16, BH203 (Clarke 1989a)
Hastings: King George V Cave (H-x6) (Goede *et al.* 1974a)
Other Mites (spp. indet.)
Acheron River: Cardia Cave (AR-x2)
Franklin River: Proina Cave (F51)
Gunns Plains: Gunns Plains Tourist Cave (GP1)
Ida Bay: Great Expectations Cave (IB129), Mystery Creek Cave (IB10), Loons Cave (IB2)
Ile du Golfe: Cave 1 (IG-x1)
Loongana: Mostyn Hardy Cave (L4)
Lower Andrew River: Cave 2 (LA-x2)
Lower Maxwell River: "Cricket Cave" (LM-x1)
Mole Creek: Kellys Pot (MC207), Kubla Khan (MC1)
Nicholls Range: Bill Nielson Cave (NR1).

2.6.3 Sub-Phylum Mandibulata
Class Crustacea

Sub-Class Copepoda

Cave dwelling copepods were unknown in Tasmania until this study and there are only a few records to date; all appear to belong to the Cyclopoidea. They are found in pools of active streamways whose sinking points drain either from native forest or pasture. The taxonomic and ecological status of these specimens is not known, although it is probable they represent epigean forms. Troglobitic Cyclopoidea found in European caves are relicts of an original tropical fauna (Vandel 1965).

Distribution Records for Copepoda
Flowery Gully: Flowery Gully Cave (FG201)
Gunns Plains: Gunns Plains Tourist Cave (GP1)
Loongana: Mostyn Hardy Cave (L4)
Mole Creek: Honeycomb Cave (MC107) (Illife 1988)
Mount Cripps: Philrod Cave (CR3)
Vanishing Falls: caves

Sub-Class Ostracoda

Illife (1988) reports the collection of ostracods from Honeycomb Cave (MC107).

Sub-Class Malacostraca

Malacostracan crustaceans are represented in Tasmanian caves by five Orders: Amphipoda (Paramelitidae, Eusiridae and Talitridae), Anaspidacea (Anaspididae, Psammaspididae and Koonungidae), Bathynellacea (Parabathynellidae), Isopoda (Oniscidea, Janiridae, Phreatoicidea) and Decapoda (Parastacidae).

Order Bathynellacea (Parabathynellidae)

To date, there is only a single record of a bathynellacean from a Tasmanian cave. *Atopobathynella* sp. (Parabathynellidae) is reported from the interstitial water of stream gravels in Exit Cave (IB14) (Goede 1975, Richards & Ollier 1976). The absence of additional records may reflect a general paucity of suitable troglorhythrostygal (=cave hyporheos) habitats, or the limited sampling effort. The Bathynellacea have a world wide distribution. These minute animals show many regressive characters such as the absence of a pigmented integument and anophthalmia. Most members of this group are strict stygobionts (Schminke 1986). They are characteristic inhabitants of groundwater and the interstitial environment and, in Tasmania, the pholeteros as well (Bathynellidae spp.) (Horwitz 1988).

Order Anaspidacea

The Anaspidacea are well represented in Tasmanian caves, including members of the Anaspididae, Psammaspididae and Koonungidae, none of which are known outside Australia. Tasmania is the centre of anaspidacean diversity, but these syncarids show a Gondwanan distribution (Australia, New Zealand and southern South America). Many of the species are stygobionts or stygophiles (Schminke 1986).

Anaspididae

Williams (1965) reported the subterranean occurrence of *Anaspides tasmaniae* from MC120, as does Scott (1960) from the stomach of an introduced trout caught in MC1. Apart from depigmentation, this cave material was identical to surface dwelling forms. Goede (1967) reported *A. tasmaniae* from H-x7 and IB14. Subsequently, Goede (1972) reported an 'eyeless' form of *Anaspides* in the Wolfe Hole (H-x8). While eyestalks are present, there are no signs of eye pigmentation or ommatidial facets. Telson spination is also different from surface dwelling *A. tasmaniae*, the posterior margin of the male holding six (or fewer) stout spines symmetrically positioned, while in the female the posterior margin of the telson has four stout spines (= telson 'cave' type) (Lake & Coleman 1977). Epigean specimens of *A. tasmaniae* normally possess many stout spines forming a spine row (= telson 'normal' type). The Wolfe Hole population appears to be completely isolated from epigean relatives and it is likely to be a distinct stygobiontic species. Some cavernicolous populations possess the 'normal type' spination (12 caves; 6 karst areas), whilst others posses the 'cave type' spination (17 caves; 3 karst areas). Some specimens carry spination which appears intermediate between these two types (= telson type 'intermediate') (4 caves; 3 karst areas). Some caves and/or karst areas contain *A. tasmaniae* which show both these types of telson spination. The distibution ranges of these different types have been mapped by O'Brien (1990). This author however, recommends caution in the use of variation in telson morphology alone as an indicator of species diversity, but clearly the conservation status of these cave forms cannot be resolved until the taxonomic relationships within the group are clarified. Electrophoretic, as well as morphometric examination will be required.

Anaspides spp. are commonly found in cave streamways, seepages and drip pools. They are generally not found in phreatic habitats, although at least one population occupies an underground lake (H-x8). Cave dwelling *Anaspides* are distributed approximately within the distribution limits of surface dwelling *A. tasmaniae,* although the Franklin River and Nicholls Range cave systems appear to be isolated from surface records, and some extension of distribution limits occurs with respect to altitude, especially in the case of cave systems at Ida Bay, Hastings, Franklin River, Nicholls Range and Precipitous Bluff (O'Brien 1990). The most southerly record of *Anaspides* is from Precipitous Bluff. Cavernicolous

Anaspides appear to be absent from north west Tasmania, where they are replaced by koonungids. Under the IUCN classification scheme, all cave forms of *Anaspides* should be regarded as 'vulnerable', solely on the basis of their highly restricted distributions (O'Brien 1990).

With respect to the subterranean occurrence of *Anaspides,* Williams (1965, 1974) has suggested firstly, that caves might have served as oligothermal refuges during periods of high temperature in the Tertiary, and secondly, that caves are refugia from trout predation. I consider that the latter is unlikely because trout penetrate into caves anyway, and coexist with *Anaspides* regularly (MC1, MC202, IB14 and JF8). Furthermore, *Anaspides* is found regularly in cave streams whether trout have been introduced into nearby surface waters or not.

Distribution Records for *Anaspides* spp.

***Anaspides tasmaniae* (telson 'normal' type) (Sp)**

Cracroft: Judds Cavern (C1)
Franklin River: Kutikina Cave (F34)
Hastings: Newdegate Cave (H-x7)
Ida Bay: Bradley Chestermans Cave (IB4)
Junee-Florentine: Growling Swallet (JF36), Khazad Dum (JF4), Rift Cave (JF34)
Lower Maxwell River: Ballawinne cave (LM-x4)
Mole Creek: Kubla Khan (MC1), Marakoopa II Cave (MC15), Herberts Pot (MC202), Kellys Pot (MC207), cave (MC-x1)
Nicholls Range: Bill Nielson Cave (NR1)
Vanishing Falls: Waterfall Spring Cave

***Anaspides* sp. (telson 'cave' type) (Sb?)**

Hastings: King George V Cave (H-x6), Wolfe Hole (H-x8)
Ida Bay: Exit Cave (IB14), Revelation Cave (IB1), Milk Run (IB38)
Junee-Florentine: Cauldron Pot (JF2), Growling Swallet (JF36), Gormenghast (JF35), Welcome Stranger (JF229), Settlement cave (JF362), Pendant Pot (JF37), Porcupine Pot (JF387), Junee Cave (JF8), caves (JF104), (JF-x3), (JF-x4)
Precipitous Bluff: Damper Cave (PB1), Persephone (PB17)

***Anaspides* sp. (telson type intermediate)**

Ida Bay: Exit Cave (IB14), Mystery Creek Cave (IB10)
Mount Anne: Deep Thought (MA10)
Mount Ronald Cross: Capricorn Cave (MR204)

***Anaspides* sp. (telson type unknown)**

Bubs Hill: Tinys Watch Hole (BH-x1)
Ida Bay: Loons Cave (IB2)
Junee-Florentine: cave (JF-x5)
Mole Creek: Honeycomb Cave (MC207) (Illife 1988)
Vanishing Falls: Salisbury River Cave

Psammaspididae

Both described species within the family Psammaspididae are strict stygobionts. The animals lack eyes, are hyaline and generally have a body length less than 10mm, although a giant undescribed form (>15mm) is known from MC202. Schminke (1974) erected this family to accommodate *Psammaspides williamsi* Schminke 1974, collected from the hyporheos of a creek in northern New South Wales. Subsequently a new species of psammaspid related to *P. williamsi* was collected from an underground spring at Devonport in north west Tasmania (Lake & Coleman 1977). Knott and Lake (1980) described the new genus and species, *Eucrenonaspides oinotheke,* which they reported as the first record of a syncarid from the free water of an underground spring, or eucrenon. This spring is not excavated in karst, but emerges from a well-weathered Tertiary basalt outcrop on the edge of what was once a tea-tree swamp, but which is now under a house. Psammaspids are known only from New South Wales and Tasmania.

Psammaspids provisionally assigned to *Eucrenonaspides* are now known from caves throughout Tasmania, although they appear to be replaced by koonungids in the far north-west and western regions. They are rare and cryptic animals.

Eucrenonaspides sp. is found in drip pools, seepages and flood overflow pools (MC13 and MC202), but rarely in larger bodies of flowing water (i.e. streamways). The drip pools or seepage pools which they inhabit are a special type of cave habitat. They are isolated pools usually fed by dripping water which originates as diffuse seepage and generally carries no coarse particulate organic matter. The pools or seepages occur most commonly in vertical shaft systems. The pools may be formed in bedrock, rimstone or in unconsolidated sediments. They are typically shallow and with a fine flocculent silt substrate. *Eucrenonaspides* can also be found in pools and seepages containing little silt, but with a gravel and pebble substrate. Seepage pools and their unique fauna are vulnerable to disturbance; a single 'careless' footstep can easily destroy, or at least fragment, the pool. In MR204 for example, *Eucrenonaspides* sp. is known only from a single pool of less than one square metre surface area (Eberhard 1989).

Distribution Records for *Eucrenonaspides* spp.

***Eucrenonaspides oinotheke* (Sb)**

Devonport: spring (Knott & Lake 1980)

***Eucrenonaspides* sp. or spp. indet. (Sb)**

Cracroft: cave CRA90-9.

Hastings: Wolfe Hole (H-x8)

Ida Bay: Skyhook Pot (IB34), Giotto Pot (IB104), Comet Pot (IB98), Salt and Pepper (IB99)

Junee-Florentine: Pendant Pot (JF37), Slaughterhouse Pot (JF337)

Mole Creek: Herberts Pot (MC202), Croesus Cave (MC13)
Mount Ronald Cross: Capricorn Cave (MR204)
Precipitous Bluff: Damper Cave (PB1)
Gray: Rum Pot (G-x3)

Koonungidae

Koonungids occur in Victoria, South Australia and Tasmania. The family is represented in Tasmania by at least two genera, *Koonunga* and *Micraspides*. However, the whole family is in need of revision (Lake *et al.* 1978). Koonungids have been recorded as temporary inhabitants of the hyporheos (Drummond 1959), from shallow surface waters and the pholeteros (Swain *et al.*1977). Koonungids are largely hypogean but lack morphological adaptations indicative of a strict hypogean existence (Schminke 1986). Some species may be regarded as stygophiles. *Micraspides* sp. lacks eyes and appears to be confined to south west and western Tasmania. As a component of the pholeteros, its distribution (along with bathynellids) appears to be mutually exclusive with those of *Allanaspides* spp., which are centred around Lake Pedder (Horwitz 1988). Specimens tentatively assigned to *Micraspides calmani* have been recorded from caves in the Lower Andrew River (LA-x1) and the Franklin River (F74).

The genus *Koonunga* appears to be confined to north west Tasmania and south east mainland Australia. *K. cursor* is found in ephemeral swamps and streams in Victoria. Ziedler (1985) described *K. crenarum* from flooded caves and sinkholes at Mount Gambier in South Australia. *K. crenarum* is the largest described form (up to 20mm) and appears to be confined to the cave refugia of south east South Australia. Like the Psammaspididae, the Koonungidae appear to be zoogeographic relicts. Specimens tentatively assigned to the genus *Koonunga* have been recorded from the groundwater in caves at Montagu (MU201) and Trowutta (T201). At nearby Redpa caves (R202) there is a similar groundwater habitat available, but koonungids were not recorded there. This may be due to clearance of the native forest causing habitat destruction and local extinction of the pholeteros communities. The relationship between the pholeteric and cavernicolous koonungids in north west Tasmania needs to be more fully investigated. Several undescribed species of *Koonunga* are known to occur in Victoria (Drummond 1959), King Island and north west Tasmania (Swain *et al.*1977).

An interesting discovery has been the finding of a large size koonungid with stygobiont facies, possibly representing a new genus. It is known only from groundwater pools in Ballawinne Cave (LM-x4) on the Maxwell River.

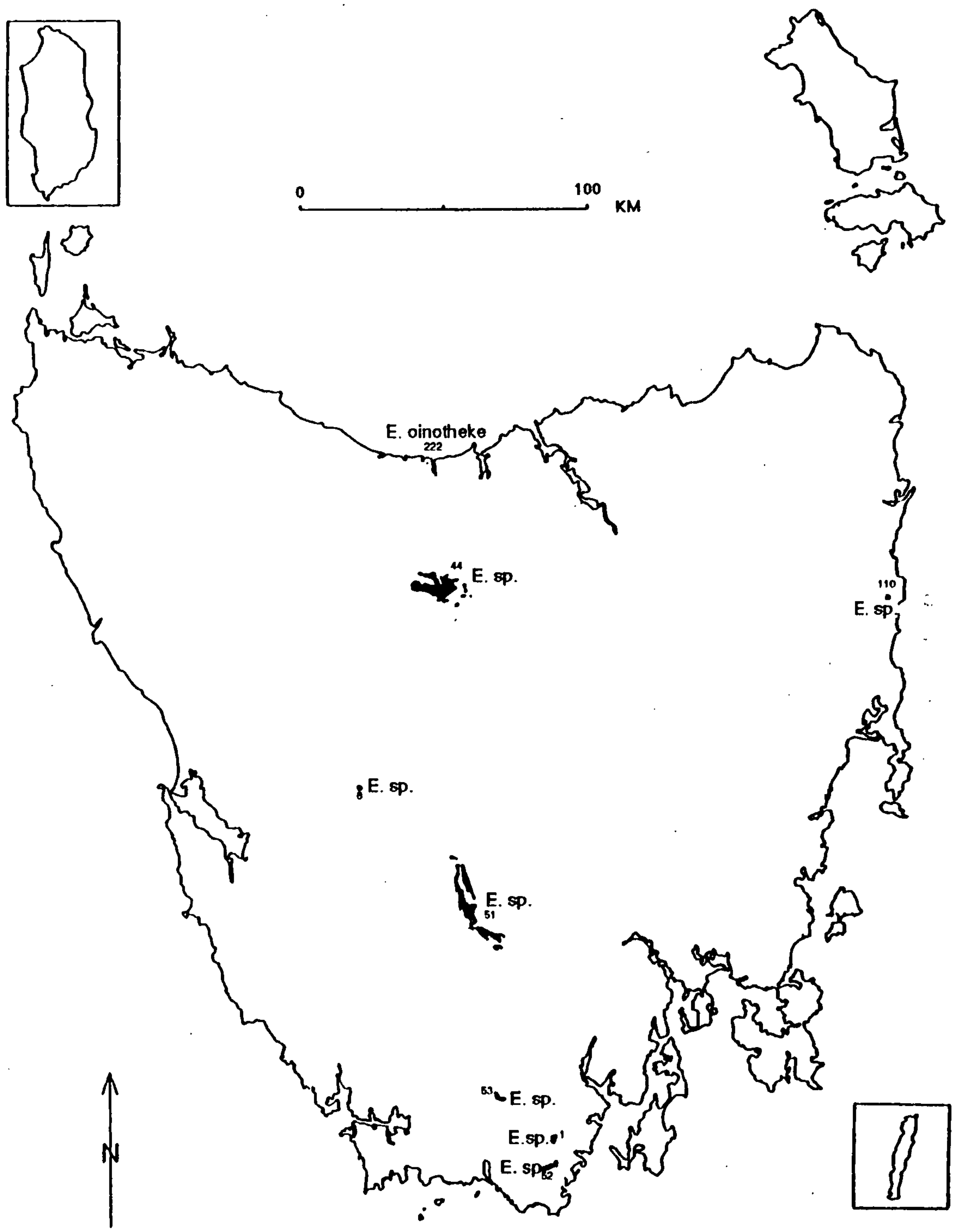


Figure 8. Distribution records for the psammaspid syncarid crustaceans *Eucrenonaspides oinotheke* and *Eucrenonaspides* sp.

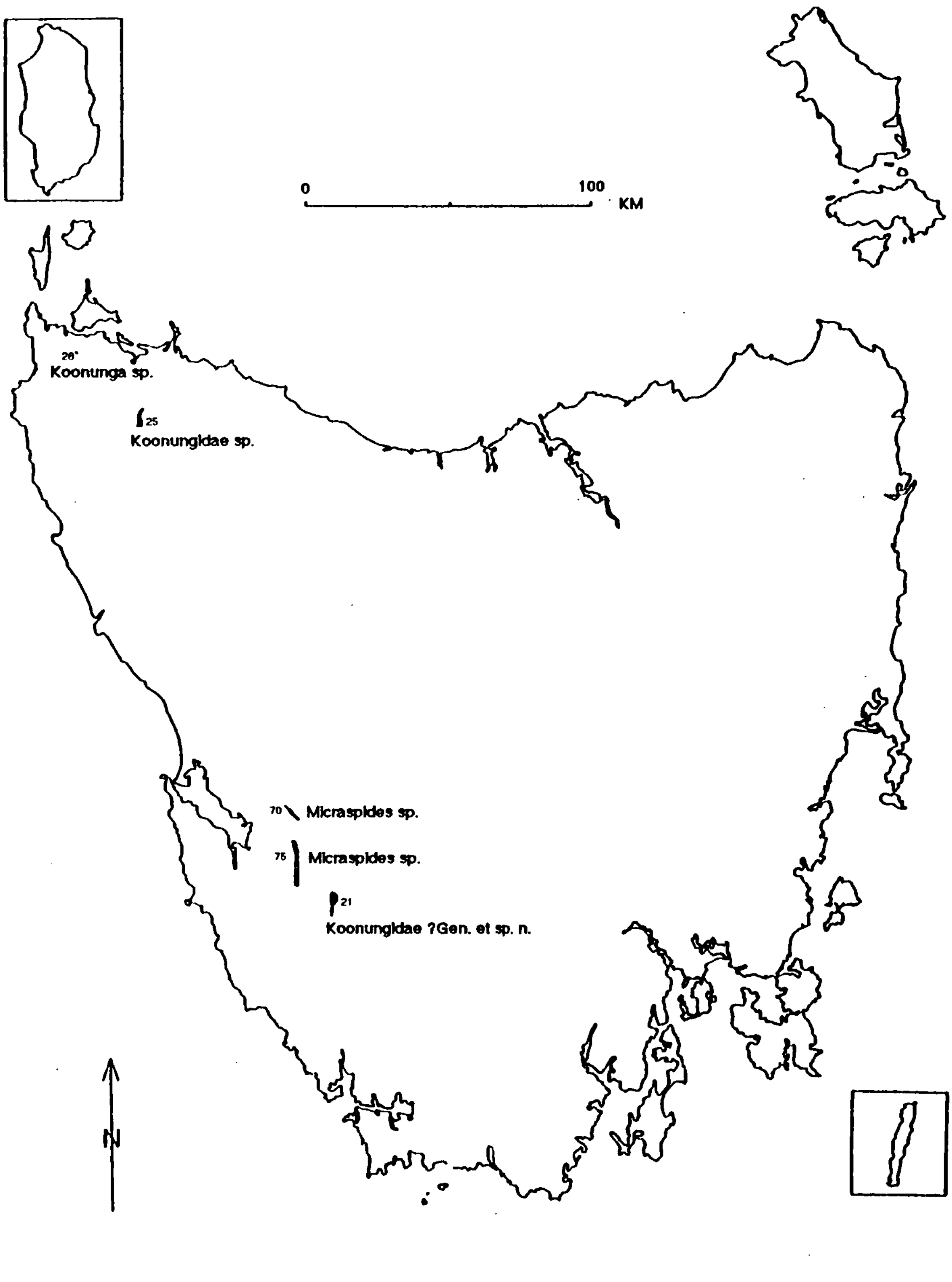


Figure 9. Cave distribution records for syncarid crustaceans in the Family Koonungidae.

Distribution Records for Koonungidae

***Micraspides ?calmani* (Sp)**
Franklin River: Gahnia Cave (F74)
Lower Andrew River: Cave 1 (LA-x1)

***Koonunga* sp.**
Montagu: Main Cave (MU201)

***Koonungidae* sp.**
Trowutta: Trowutta Arch (T201)

***Koonungidae* ?Gen. et sp. n. (Sb)**
Lower Maxwell River: Ballawinne Cave (LM-x4)

Division Peracarida
Order Isopoda
Sub-Order Oniscidea

The terrestrial Isopoda (Sub-Order Oniscidea) are a common component in cave faunas throughout much of the world (Vandel 1965), and they are well represented in Tasmania (Green 1961; 1971). Tasmanian cavernicolous oniscoids are reviewed by Eberhard (1990b). They include species belonging to the families Styloniscidae, Armadillidae, Ligiidae and Scyphacidae. Styloniscid species are the dominant cavernicoles. They are the most primitive fully terrestrial Tasmanian oniscoids, and they are the most vulnerable to desiccation (Green 1974). They are the characteristic Oniscidea in Tasmanian wet forests (Green 1974). They typically occur in leaf litter and under wood and stones in wet sclerophyll and rainforest. The Styloniscidae are adapted to cool, dark and moist environments and are likely candidates for cave life.

Styloniscus is the dominant genus, which also occurs in the Great Dividing Range, New South Wales and south west Western Australia. *Styloniscus nichollsi* is the most widely distributed species and occurs in a variety of habitats, including dry sclerophyll forest (Green 1974). This species is a common troglophile, recorded from numerous caves around the State. Other *Styloniscus* species occurring as adventitious or facultative cavernicoles include *S. squarrosus, S. maculosus* and *S. hirsutus*. These species are most commonly associated with organic debris near entrances, but also may be found on sediment banks and rock surfaces some distance underground.

Most closely related to *S. nichollsi* are two new species with troglobitic facies, *Styloniscus* sp. nov. A and *Styloniscus* sp. nov. B. Species A is depigmented, or with traces of purplish colouration, and pigmented ocelli (A. Green pers. comm.) It is known only from three caves at Ida Bay (IB2, IB4, IB110) (Eberhard 1990b). Species B has a body which is colourless, or almost so, and in the majority of cases there is no indication of eyes although there may be occasional spots of pigment in place of ocelli. This species is widely distributed and has been recorded from 21 caves in 11 karst areas. Both these species are characteristic inhabitants of the deep cave zone, but they have also been collected close to entrances. They are found on a wide range of substrate types including rock surfaces, flowstone, sediment banks, tree roots, logs and litter. They may be abundant in streamways and flood prone sections of passage. In MC4 a specimen of Species B was observed walking underwater across the bottom of a drip pool.

The identifications given below were provided by A. Green.

<u>Distribution Records for Styloniscidae</u>

***Styloniscus* sp. nov. A**

Ida Bay: Loons Cave (IB2), Bradley Chestermans Cave (IB4), Arthurs Folly Cave (IB110)

***Styloniscus* sp. nov. B**

Bubs Hill: 1935 Cave (BH4); Minimoria (BH202), Thylacine Lair (BH203) (Clarke 1989a)
Cracroft: Judds Cavern (C1)
Flowery Gully: Flowery Gully Cave (FG201)
Gunns Plains: Gunns Plains Tourist cave (GP1)
Hastings: King George V Cave (H-x6)
Ida Bay: Little Grunt (IB23), Comet Pot (IB98), Giotto Pot (IB104), Loons Cave (IB2), Hobbit Hole (IB15), IB91
Junee-Florentine: Welcome Stranger (JF229), Owl Pot (JF221)
Loongana: Mostyn Hardy Cave (L4), Swallownest Cave (L5)
Mole Creek: Kubla Khan (MC1), Marakoopa Cave (MC120)
Precipitous Bluff: Cueva Blanca (PB4)
Redpa: Glue Passage Cave (R202)
Vanishing Falls: Salisbury River Cave

Styloniscus nichollsi

Acheron River: Cardia Cave (AR-x2), Cave 1 (AR-x1)
Hastings: King George V Cave (H-x6)
Mole Creek: Kellys Pot (MC207); Georgies Hall Cave (MC201), Baldocks Cave (MC32), Herberts Pot (MC202), Scotts Cave (MC52) (Terauds 1973)
North Lune: Spider Den (NL3) (Clarke 1990)

Styloniscus ?nichollsi

Gordon-Sprent: Cave 1 (GS-x1)
Hastings: King George V Cave (H-x6)
Ida Bay: Mystery Creek Cave (IB10)
Junee-Florentine: Gelignite Pot (JF391)
Lower Maxwell River: "Cricket" Cave (LM-x1)
Mole Creek: Herberts Pot (MC202)

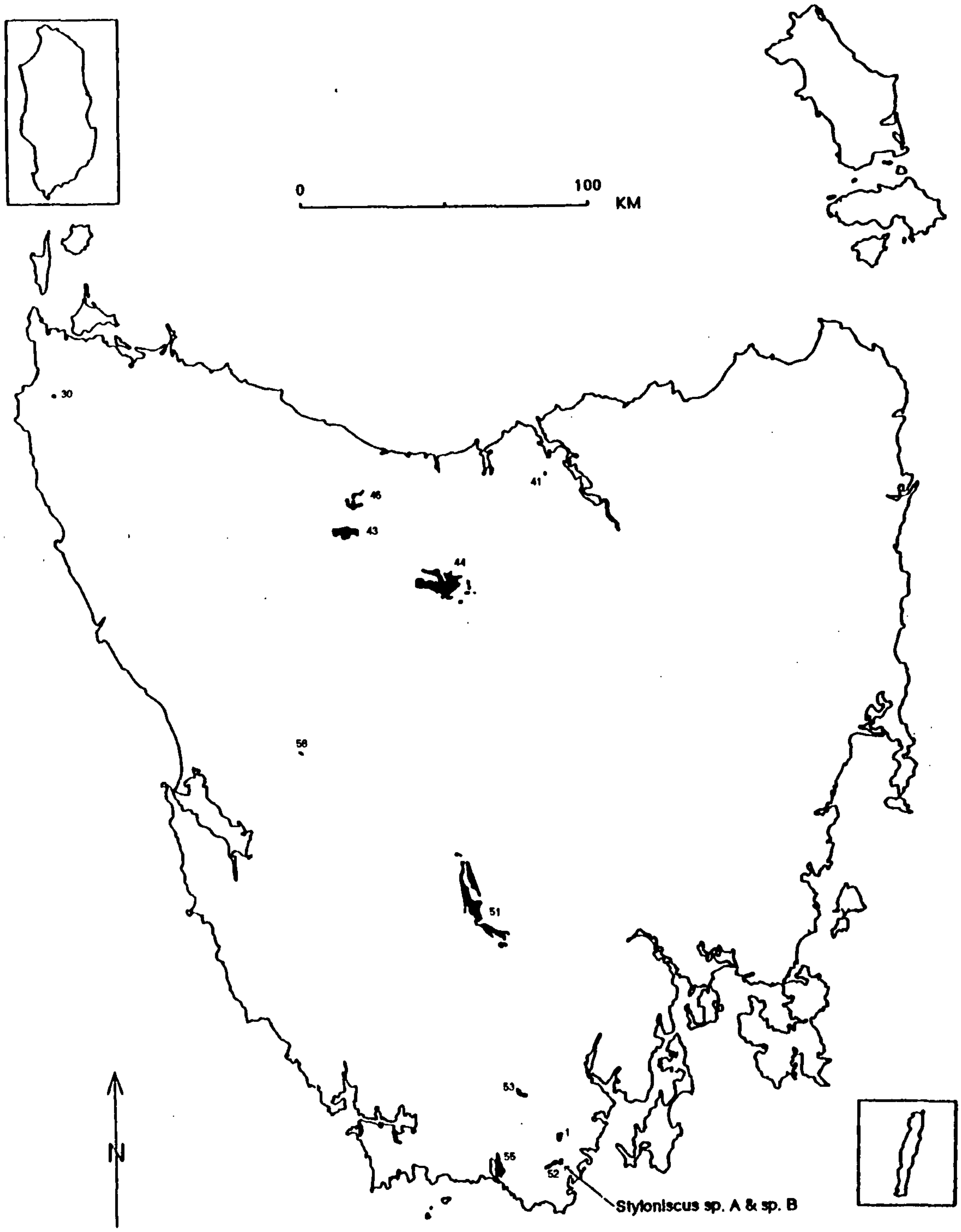


Figure 10. Distribution records for troglobitic isopod crustaceans in the genus *Styloniscus*. All unlabelled records refer to *Styloniscus* sp. B.

Styloniscus squarrosus
Bubs Hill: Collapse Cave (BH15) (Clarke 1989a)
Mount Anne: Annakananda (MA4)
Styloniscus ?squarrosus
Franklin River: Kutikina Cave (F34)
Styloniscus maculosus
Bubs Hill: caves (BH2, BH5, BH16, BH203) (Clarke 1989a)
Ida Bay: Exit Cave (IB14) (Richards & Ollier 1976)
North Lune: Spider Den (NL3) (Clarke 1990)
Styloniscus hirsutus
Bubs Hill: Highway Holocaust (BH13) (Clarke 1989a)
***Styloniscus* [=HEC LGRSS sp. no. 3]**
Junee-Florentine: Cashions Creek Cave (JF6), Pendant Pot (JF37)
Loongana: Mostyn Hardy Cave (L4)
***Notoniscus* sp.**
Franklin River: Kutikina Cave (F34)
Styloniscidae spp. indet.
Flowery Gully: Flowery Gully Cave (FG201)
Franklin River: Kutikina Cave (F34)
Junee-Florentine: Asteroid Pot (JF366), Cauldron Pot (JF2), Gormenghast (JF35), Khazad Dum (JF4), Pendant Pot (JF37), Splash Pot (JF10), Threefortyone (JF341), "Wherrets" Cave (JF-x6)
Loongana: Leven Cave (L3), Mostyn Hardy Cave (L4)
Mole Creek: Croesus Cave (MC13)
Redpa: cave (R-x1)
Risbys Basin: Ray Bender's Cave
Upper Weld: Weld River Arch

The other families of Oniscidea recorded from Tasmanian caves belong to the Armadillidae, Ligiidae and Scyphacidae. Members of the Armadillidae include *Echinodillo cavaticus* Green 1963 (described from material collected in Ranga Cave (RA-x1), Flinders Island) and genera close to *Acanthodillo* (IG-x1) and *Cubaris* (N-x2) respectively. The supralittoral Scyphacidae (*Deto marina*) and Ligiidae (*Ligia australiensis*) are recorded from sea caves on Ile du Golfe. All of the above are either troglophiles or accidental cavernicoles.

Distribution Records for Armadillidae
Echinodillo cavaticus
Flinders Island: Ranga Cave (RA-x1)
(close to) *Acanthodillo* sp.
Ile du Golfe: Cave 1 (IG-x1)
(close to) *Cubaris* sp.
Nelson River: Central Cave (N-x2)

Distribution Records for Scyphacidae

Deto marina

Ile du Golfe: Cave 1 (IG-x1)

Distribution Records for Ligiidae

Ligia australiensis

Ile du Golfe: Cave 4 (IG-x4)

Sub-Order Phreatoicoidea

The first phreatoicids were collected from wells sunk into alluvial plains of Holocene river gravels, silts and sands in New Zealand. Phreatoicids are a Gondwana group restricted to Australia, New Zealand, India and South Africa. Stygobionts occur on all these Gondwana fragments except South Africa. Phreatoicids are very diverse in Tasmania (Nicholls 1942; 1943), and more than half the known genera and species are Tasmanian (Knott 1986). An unpublished revision by Knott (1975) recognised 46 species of extant Phreatoicoidea, 12 of them being subterranean. The latest review of the group is by Knott (1986) and it is evident that the systematics still have to be fully understood.

In Tasmania there are two groups with stygobiont facies, the Hypsimetopinae (Amphisopidae) and Paraphreatoicinae (Phreatoicidae). Species in these groups show morphologies which include blindness, white colour, attenuated appendages, vermiform body and short abdominal epimera scarcely covering the base of the pleopods (with the possible exception of *Neophreatoicus assimilis*) (Knott 1986). Within the Hypsimetopinae, the several forms of *Hypsimetopus* and *Phreatoicoides* inhabit pholeteros of north west Tasmania, but have also been collected from surface waters of buttongrass (*Gymnoschoenus sphaerocephalus*) plains, and runnels in *Nothofagus* rainforests. Hypsimetopines and paraphreatoicines have been collected from caves at Trowutta (T201), Acheron River (AR-x1) and Mole Creek (MC75 & Den Plain).

Phreatoicids are rarely encountered in cave streams although such habitats in Australia are now known to harbour a diverse crustacean fauna (Knott 1986). Rather, subterranean phreatoicids are specialised inhabitants of the phreas or groundwater habitats. This habitat is characterised by slow flowing water of high clarity, with a substrate of fine flocculent silt. There is relatively little food input to these detritus based ecosystems. Sampling the karst phreas is often difficult, but where cave passages intersect the local water table, phreatoicids may be found. A new genus and species of paraphreatoicine is known from two stream caves (MC75, MC120). Unidentified phreatoicids with a robust body form have been collected in a drip pool at Mount Weld (MW-x1).

Distribution Records for Phreatoicoidea

Paraphreatoicinae Gen. et sp. n. (Knott 1975) (Sb)

Mole Creek: Marakoopa II Cave (MC120), Mersey Hill Cave (MC75)

Hypsimetopinae or Phreatoicidae spp. (Sb)

Acheron River: Cave 1 (AR-x1)

Mole Creek: caves on Den Plain

Trowutta: Trowutta Arch (T201)

Phreatoicoidea sp. (Sp?)

Mount Weld: Arrakis (MW-x1)

Asellota

The Asellota are represented in Australian freshwaters by species in the genera *Pseudasellus* and *Heterias*. These species are found living freely in freshwater streams, pools and lakes in southern Victoria, South Australia and Tasmania (Williams 1980). A new species of janirid isopod is known from caves at Yanchep in Western Australia (Jasinska & Knott 1991). They are recorded from crayfish burrows and caves, as well as the benthos and hyporheos of rivers in Tasmania (Coleman 1978). An unpublished revision by Roberts (1973) suggests that *P. nichollsi* should be transferred to the genus *Heterias*.

Two species of *Heterias* are recognised in Tasmania (Roberts 1973), but additional taxa, including stygobiontic forms, are known. *H. petrensis* is pigmented and eyed, and has been recorded from the littoral zone of lakes in Central Tasmania (Roberts 1975). Animals tentatively placed in the same species are now known from caves at Ida Bay (IB110) and the Maxwell River (LM-x1)). Also from Ida Bay is a possible new species (P. Horwitz pers. comm.) which is blind and unpigmented, but close to *H. petrensis*. This same form, or a similar form, has also been collected from IB34 and NR1. The Ida Bay specimens were collected in seepage streams, while the Nicholls Range material came from the benthos of a seep as well as the troglorhythrostygal (= cave hyporheos) habitat. These specimens are blind and depigmented.

H. pusilla is a blind form first described from a freshwater pool in Victoria (Sayce 1900). It has been recorded from the benthos and hyporheos of the Gordon River (Coleman1978). *Pseudasellus nichollsi* Chappuis 1951 is also blind and unpigmented. It is known from numerous surface localities in Tasmania, but not from caves.

Heteriids occur in underground streamways only rarely. They are more common in phreatic habitats in north west Tasmania, but also occur in seepage waters and the hyporheos of cave streams. The species found in phreatic habitats at R202 and T201 appear to be adapted to a food-poor environment.

Stygobiontic Asellota are known throughout the northern hemisphere, as well as in South Africa and Madagascar (Grindley 1963; Coineanu 1986; Henry, Lewis & Magniez 1986). Roberts (1973) places *Heterias* within the family Janiridae (Janiroidea).

Some of the material listed below was identified by Dr P. Horwitz.

Distribution Records for *Heterias* spp.
***Heterias petrensis* (Sp)**
Ida Bay: Arthurs Folly Cave (IB110)
Lower Maxwell River: "Cricket" Cave (LM-x1)
***Heterias* sp. (near *petrensis*) (Sb)**
Ida Bay: Arthurs Folly Cave (IB110), Skyhook Pot (IB34)
Nicholls Range: Bill Nielson Cave (NR1)
***Heterias* sp. (Sb)**
Junee-Florentine: Khazad Dum (JF4)
Loongana: Mostyn Hardy Cave (L4)
Redpa: Glue Passage Cave (R202)
Trowutta: Trowutta Arch (T201)
Vanishing Falls: Salisbury River Cave

Amphipoda
Australian cavernicolous amphipods were reviewed by Knott (1985). Nearly all Tasmanian freshwater cavernicolous amphipods belong in the family Paramelitidae, of the Crangonyctoidea which is the most diverse group in Australian freshwaters (Williams & Barnard 1988). The genera recorded are: *Antipodeus, Austrogammarus, Giniphargus* and a genus close to *Hurleya*. There are single cave records for the families Eusiridae and Ceinidae. Fully terrestrial amphipods (Talitridae) are found in litter deposits which originate from gravity input at entrances. All specimens recorded are referable to epigean species.

Antipodeus is the dominant genus, with a high diversity of both stygophilic and stygobiontic forms. *Antipodeus* stygobionts occur at Precipitous Bluff, Vanishing Falls, Cracroft, Junee-Florentine, Ida Bay and Gunns Plains. All of these karst areas are situated at the base of, or proximal to, high mountain ranges which were subject to periods of glaciation during the Cainozoic. *Antipodeus* sp. from Precipitous Bluff is the most highly troglomorphic representative in the genus, because it completely lacks both eyes and pigment, and its appendages are relatively long.

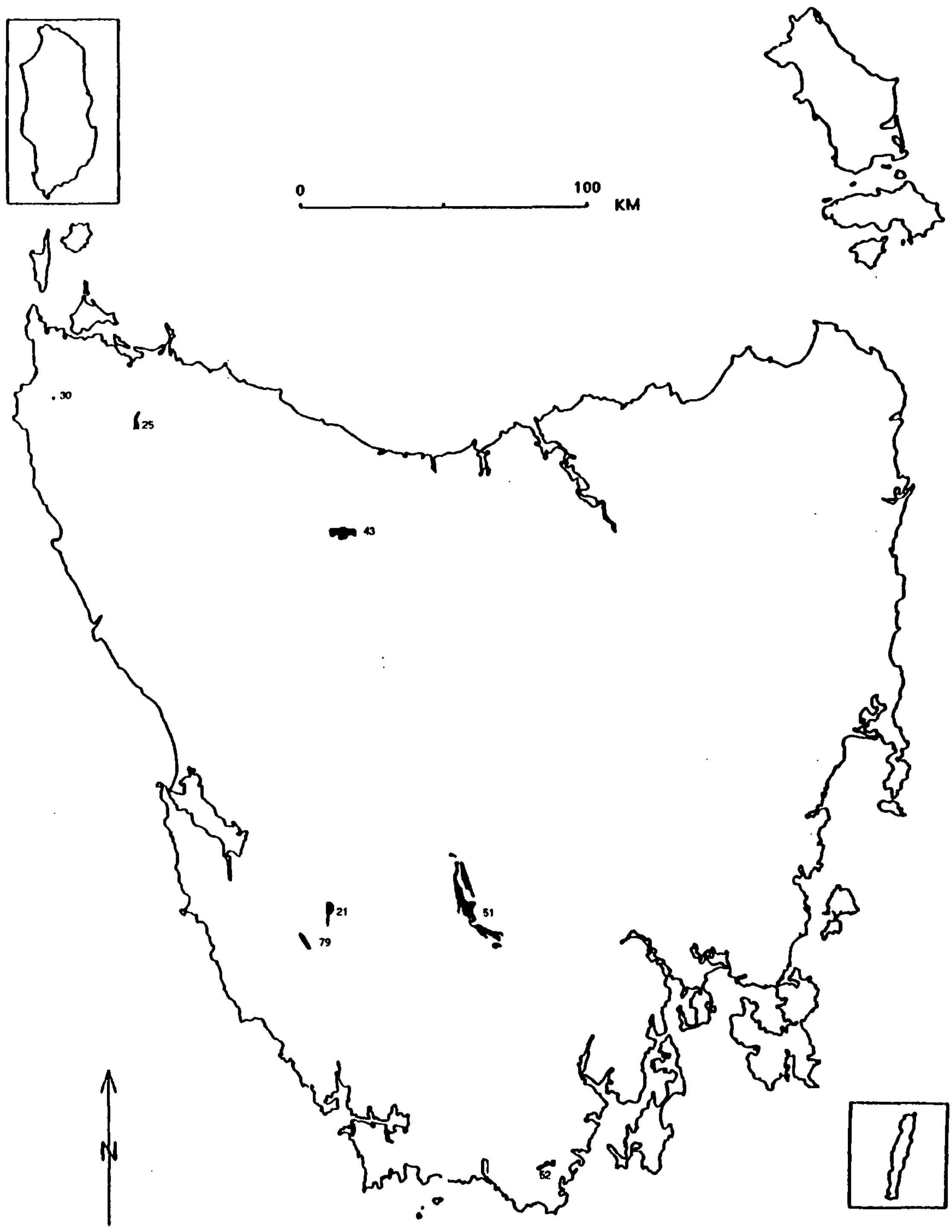


Figure 11. Cave distribution records for isopod crustaceans in the genus *Heterias*.

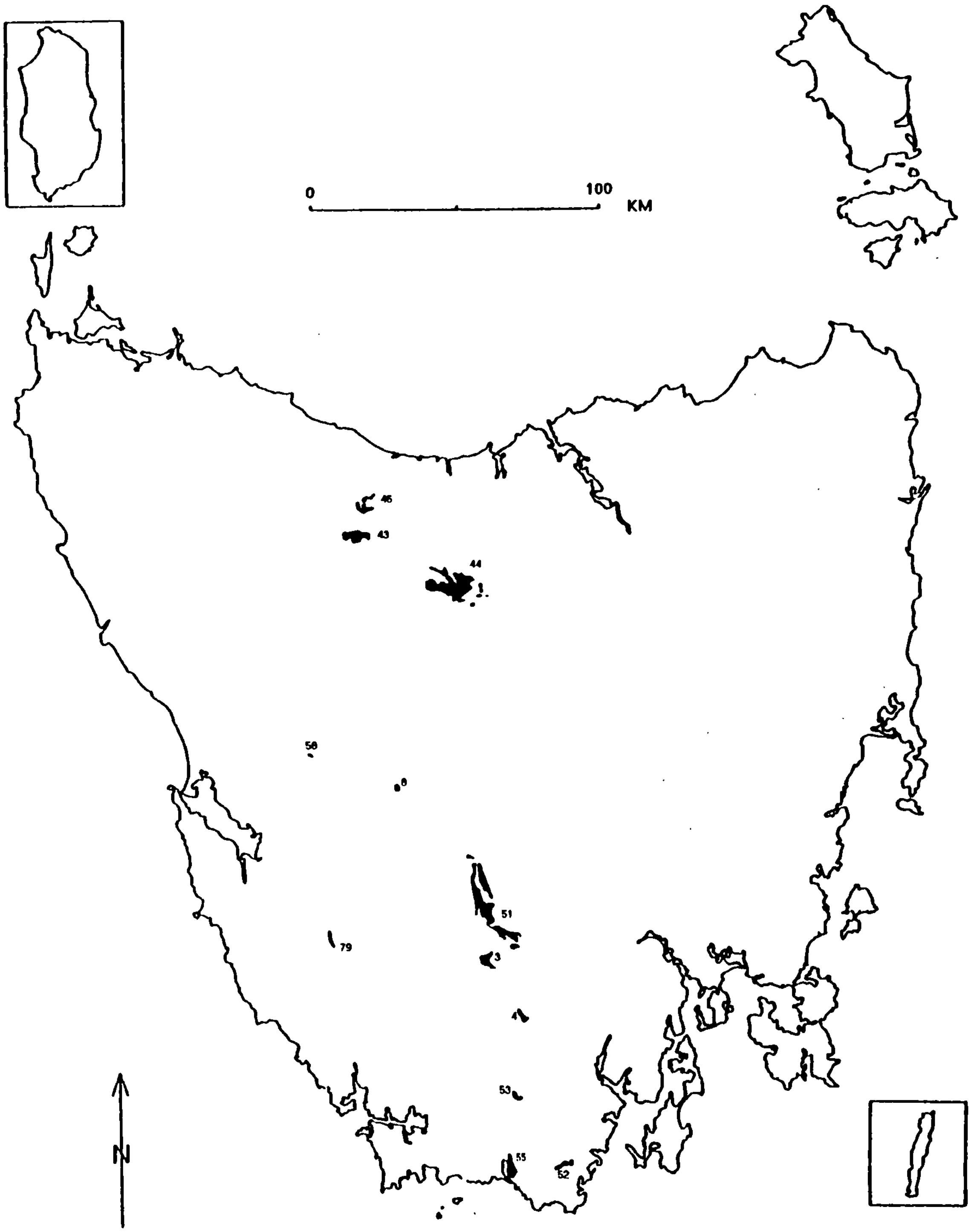


Figure 12. Cave distribution records for amphipod crustaceans in the genus *Antipodeus*.

Austrogammarus is regarded as the most plesiomorphic genus of Australian paramelitids (Williams & Barnard 1988). *Austrogammarus* species have only beem recorded from the western riverine karsts, Gunns Plains and Loongana. The genus is not recorded from caves in southern karst areas although epigean populations do occur in these areas.

The other major freshwater genus, *Neoniphargus*, is not recorded from caves, although it is a component of other stygal habitats including crayfish burrows and interstitial environments. *Giniphargus* and the genus close to *Hurleya* both occur in low altitude karst areas. The Loongana karst area has the highest recorded diversity (three genera and five species).

Distribution Records for *Antipodeus* spp.

***Antipodeus* 'stygobiont 1'**
Precipitous Bluff: Bauhaus (PB6), Cueva Blanca (PB4)
***Antipodeus* 'stygobiont 2'**
Mount Weld: Arrakis (MW-x1)
***Antipodeus* 'stygobiont 2a'**
Ida Bay: Comet pot (IB98)
Mole Creek: Little Trimmer Cave (MC38)
***Antipodeus* 'stygobiont 3'**
Cracroft: Judds Cavern (C1)
Gunns Plains: Gunns Plains Tourist Cave (GP1)
Junee-Florentine: Splash Pot (JF10), Gormenghast (JF35), Three Falls Cave (JF225), Threefortyone (JF341)
***Antipodeus* 'stygobiont 4'**
Junee-Florentine: Cauldron Pot (JF2)
***Antipodeus* 'stygobiont c.f. *wellingtoni*'**
Junee-Florentine: Tassy Pot (JF223), Threefortyone (JF341)
Antipodeus (unidentifed stygobiont)
Vanishing Falls: Salisbury River Cave
Antipodeus 'c.f. ***wellingtoni***'
Mount Ronald Cross: Capricorn Cave (MR204)
Antipodeus franklini
Nicholls Range: Bill Nielson Cave (NR1)
Ida Bay: Loons Cave (IB2)
***Antipodeus* '?*franklini*'**
Junee-Florentine: Cauldron Pot (JF2)
Upper Weld: Weld River Arch
Antipodeus antipodeus
Mole Creek: Kellys Pot (MC207)

Antipodeus **'sp. A'**
Bubs Hill: Main Drain (BH8)
Cracroft: Judds Cavern (C1)
Ida Bay: Mystery Creek cave (IB10)
Junee-Florentine: Khazad Dum (JF4), Growling Swallet (JF36)
Loongana: Mostyn Hardy Cave (L4)
Antipodeus **'sp B'**
Junee-Florentine: Growling Swallet (JF36)
?*Antipodeus* **sp. A**
Junee-Florentine: Khazad Dum (JF4), surface
?*Antipodeus* **sp. B**
Ida Bay: Skyhook Pot (IB34)
Antipodeus sp. **?**
Mole Creek: Croesus Cave (MC13)

Distribution Records for *Austrogammarus* spp.
Austrogammarus ***'smithi*** **?'**
Gunns Plains: cave (GP4)
Loongana: Mostyn Hardy Cave (L4)
Lower Andrew River: Cave 1 (LA-x1)
Austrogammarus **'not *smithi*'**
Gunns Plains: Gunns Plains Tourist Cave (GP1)
Austrogammarus **'not *smithi* 1'**
Loongana: Mostyn hardy Cave (L4)
Austrogammarus **'not *smithi* 2'**
Loongana: Leven Cave (L3)
Lower Andrew River: Cave 2 (LA-x2)
Lower Maxwell River: "Cricket Cave" (LM-x1)
Austrogammarus **'sp. a'**
Franklin River: Proina Cave (F51), Gahnia Cave (F74), surface

Distribution Records for Genus ? close to *Hurleya*
sp. A
Loongana: Leven Cave (L3), Mostyn Hardy Cave (L4)
Lower Andrew River: Cave 1 (LA-x1)
Montagu: Main Cave (MU201)
Trowutta: Trowutta Arch (T201)
sp. B
Ida Bay: Arthurs Folly Cave (IB110)
? sp. B
Lower Maxwell River: "Cricket Cave" (LM-x1)
Nicholls Range: Bill Nielson Cave (NR1)

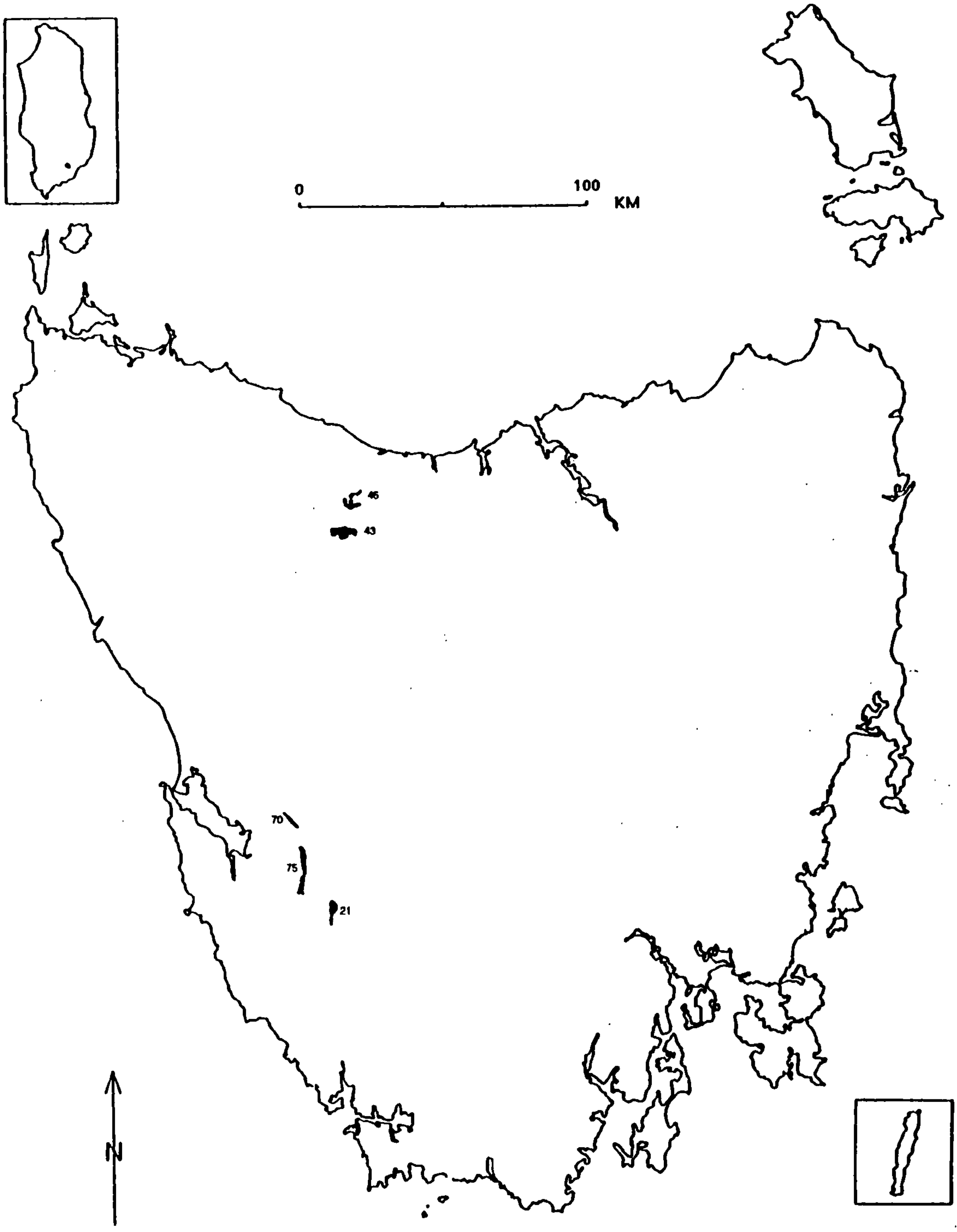


Figure 13. Cave distribution records for amphipod crustaceans in the genus *Austrogammarus*.

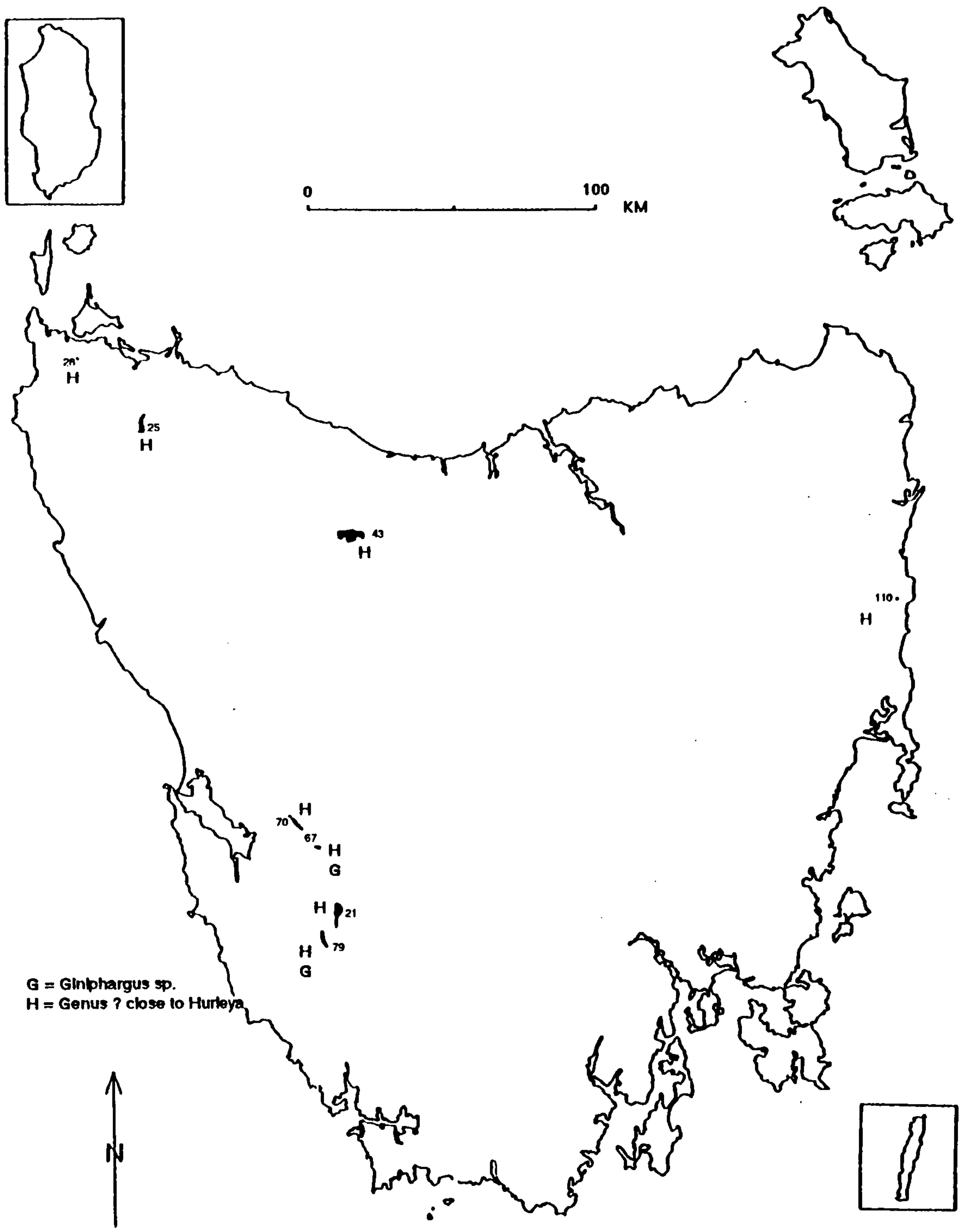


Figure 14. Cave distribution records for amphipod crustaceans in the genus *Giniphargus*, and an undescribed genus close to *Hurleya*.

sp. C
Acheron River: cave 1
sp. indet.
Gray: Rum Pot (G-x3)

Distribution Records for *Giniphargus* spp.
***Giniphargus* (not *pulchellus*)**
Nicholls Range: Bill Nielson Cave (NR1)
?Giniphargus sp.
Acheron River: Cave 1 (AR-x1)

Distribution Records for Ceinidae
Afrochiltonia australis
Trowutta: Trowutta Arch (T201)

Distribution Records for Eusiridae
Paraleptamphopus sp.
Lower Andrew River: Cave 2 (LA-x2)
Franklin River: surface

Distribution Records for Talitridae
Keratroides vulgaris
Bubs Hill: Thylacine Lair (BH203), caves (BH13, BH15 & BH16) (Clarke 1989a)
Loongana: Mostyn Hardy Cave (L4)
North Lune: Spider Den (NL3) (Clarke 1990)
Mount Wellington: Cave 1 (WE-x1)
Upper Weld River: Weld River Arch
Keratroides angulosus
Gray: Rum Pot (G-x3)
Neorchestia plicibrancha
Franklin River: Kutikina Cave (F34)
spp. indet.
Ida Bay: The Potholes (ref. Eberhard 1990a)
Mole Creek: Kubla Khan (MC1)

Division Eucarida
Order Decapoda
Tasmania has a diverse assemblage of freshwater crayfish belonging to the family Parastacidae but, unlike the North American crayfishes, parastacids do not seem to have colonised caves extensively and no fully troglobitic species are known in the Australian fauna (Growns & Richardson 1990). With their burrowing habits, the

parastacids would seem to be likely candidates for subterranean existence. Crayfish are recorded occasionally from caves, but they appear to be unmodified surface species.

Crayfish in Tasmania have been found in two types of cave habitat: streamways and the phreas. When found in cave streams, these streams are usually provided with a relatively high organic input, or have a reasonably direct connection to the surface. Species in the genera *Engaeus, Astacopsis* and *Parastacoides* have been recorded, the former from phreatic pools and the latter two from streams. A juvenile *Parastacoides* sp. collected from F74 shows possibly troglomorphic facies, including depigmentation and elongated antennae. An *Engaeus* sp. is known from caves in New South Wales, whilst other parastacid species inhabit caves in Western Australia and sinkholes in South Australia.

There is an unusual occurrence of a breeding population of the Giant Freshwater Crayfish (*Astacopsis gouldi*) in the Gunns Plains Tourist Cave (GP1) (P. Hamr pers. comm.). These animals are an attraction on the cave tour. The stream probably carries a high nutrient load because it drains off pasture, and there is abundant wood in the streamway of the tourist section. Crayfish have been found well beyond the tourist section and into the further reaches of the cave. The cave appears to provide a refuge from fishing for this species. This is the only known cave population of this species (one other cave nearby (GP2) was searched unsuccessfully). There are unconfirmed reports of crayfish in the entrance pool of Mostyn Hardy Cave (L4), and also a report of a 'white crayfish' from the Julius River caves. Furthermore, there are unconfirmed sightings of crayfish (probably *Astacopsis franklinii*) from IB14 and a cave stream at Gray. There are confirmed records of *A. franklinii* from IB10 and a cave near the Maxwell River.

<u>Distribution Records for Parastacidae</u>

Astacopsis gouldi

Gunns Plains: Gunns Plains Tourist Cave (GP1)

Loongana: Mostyn Hardy Cave (L4), unconfirmed report

***Astacopsis* sp.**

Julius River: Julius River Caves (JR2 or JR5), unconfirmed report

Gray: Loongana: cave (L8), unconfirmed report

Astacopsis franklinii

West Maxwell-Algonkian: unidentified cave

Ida Bay: Mystery Creek Cave (IB10); Exit Cave (IB14), unconfirmed report

Engaeus fossor

Montagu: Main Cave (MU201)

Redpa: Glue Passage Cave (R202)

Parastacoides tasmanicus inermis

Franklin River: Kutikina Cave (F34)

***Parastacoides* sp. (juvenile)**
Franklin River: Gahnia Cave (F74)

2.6.4 Class Diplopoda

Unfortunately, little can be said concerning cavernicolous millipedes, although they are a common element in some cave communities. They are widespread in Tasmanian caves, and both troglophilic and troglobitic, as well as accidental, forms are represented. Cave millipedes were first reported by Goede (1967, 1977a). This early material included the epigean species *Lissodesmus modestus* (recently redescribed by Jeekel 1984) and *Pseudoprionopeltis hardyi*. Most interesting were two new species of troglobite assigned to the family Dalodesmidae, which were collected at Ida Bay and the Florentine Valley.

The ecological status of much of the material collected remains unclear. Accidentals such as *L. modestus* and *P. hardyi* occur as part of the litter fauna at the base of entrance shafts. Some troglophilic species appear to invade caves from surrounding forest habitats. The troglobitic forms are some of the few terrestrial cavernicoles found in the truly deep cave zone. As detritivores, they can be found roaming sediment banks, flood litter and rock surfaces (which may be periodically inundated) in extremely food-poor regions of caves. They are also found on calcite formations, tree roots and the walls of shafts with dripping water. They are sometimes found as 'colonies' in caves (same clutch?) and their abundance is seasonally quite variable in some caves (A. Goede pers. comm.). The distribution of the troglobitic forms is scattered; they are recorded from only a few karst areas and are most prominent in caves at Ida Bay and Junee-Florentine. Unfortunately the taxonomy of these forms is too poorly known to comment on the likely diversity.

<u>Distribution Records for Diplopoda (and ecological status where known)</u>
***Lissodesmus modestus* (Ac/Tx?)**
Hastings: Newdegate Cave (H-x7) (Goede 1977a)
***Lissodesmus sp.* (Ac/Tx?)**
Hastings: King George V Cave (H-x6) (Goede 1977a)
***Pseudoprionopeltis hardyi* (Ac/Tx?)**
Junee-Florentine: Cashions Creek Cave (JF6) (Goede 1977a)
Diplopoda spp.
Bubs Hill: 1935 Cave (BH4) (?), Minimoria (BH202) (Ac)
Eugenana: Sherrils Cave (E201) (?)
Flowery Gully: Flowery Gully Cave (FG201) (Ac)
Franklin River: Gahnia Cave (F74) (Tp?), Kutikina Cave (F34) (Ac & Tp?), Proina Cave (F51) (Tp?)
Gordon-Sprent: Cave 1 (GS-x1) (Ac/Tx?)

Gray: Rum Pot (G-x3) (Ac)
Gunns Plains: Gunns Plains Tourist Cave (GP1) (?)
Ida Bay: Exit Cave (IB14) (Dalodesmidae Tb), Mystery Creek Cave (IB10) (Tb), Arthurs Folly Cave (IB110) (Tb), Cyclops Pot (IB57) (Tb), Loons Cave (IB2) (Tb), Midnight Hole (IB11) (Tb), Milkrun (IB38) (Tb), Mini Martin (IB8) (?), Bradley Chestermans Cave (IB4) (?)
Junee-Florentine: Gormenghast (JF35) (Dalodesmidae Tb), Burning Down The House (JF402) (Tb), Growling Swallet (JF36) (Tb), Junee Cave (JF8) (Tb), Porcupine Pot (JF387) (Tb), Pendant Pot (JF37) (Tb), Owl Pot (JF221) (Tb), Rift Cave (JF34) (Tb), Serendipity (JF344) (Tb), Tassy Pot (JF223) (Tb), The Chairman (JF99) (Tb), Voltera (JF207) (Tb), Wherrets Cave (JF-x6) (Tb), Troll Hole (JF-x1) (Tb), Khazad Dum (JF4) (Tb?), Cashions Creek Cave (JF6) (?), Varmint Pot (JF376) (Ac), cave x2 (Ac/Tx?)
Loongana: Leven Cave (L3) (Tb? & Tp & Ac), Mostyn Hardy Cave (L4) (Tp & Tb?)
Lower Andrew River: Cave 1 (LA-x1.?), Cave 2 (LA-x2.?)
Lower Maxwell River: "Cricket" Cave (LM-x1) (Ac)
Mount Anne : cave MA14 (?), Deep Thought (MA10) (Tb?), Col-In-Cavern (MA1) (?)
Mount Wellington: Cave 2 (WE-x2) (Ac)
Mount Weld: Arrakis (MW-x1) (Tb)
Nicholls Range: Bill Nielson Cave (NR1) (Ac & ?)
Precipitous Bluff: unidentified cave (?Dalodesmidae) (Kiernan & Harris 1973), Quetzalcoatl Conduit (PB3) (Tb), Bauhaus (PB6) (Tb), Damper Cave (PB1) (Tb)
Risbys Basin: Ray Bender's Cave (Tp)
Upper Weld River: Weld River Arch (Ac/Tx?), Keyhole Cavern (Ac)
Vanishing Falls: Salisbury River Cave (Tb & Tp)

2.6.5 Class Chilopoda

All chilopods recorded from Tasmanian caves appear to be accidentals. Individuals are recorded occasionally, generally near cave entrances or below entrance shafts in the dark zone. Specimens include a craterostigmomorph (*Craterostigmus tasmanianus*) and geophilomorphs.

Distribution Records for Chilopoda
Craterostigmus tasmanianus
Junee-Florentine: The Chairman (JF99)
Chilopoda spp.
Franklin River: Proina Cave (F51)
Loongana: Mostyn Hardy Cave (L4)
Mount Anne: Col-In-Cavern (MA1)

2.6.6 Class Symphyla

Symphyla are common in Tasmanian caves. They are also common in rainforest habitats on the surface, where they may be found in rotting logs, moss and litter. In caves, Symphyla can be found well into the deep cave zone. They are often found near drip pools, logs and litter, flowstone, running water and recently flooded mudbanks, but are also wide roaming. They are fast moving, and nearly always appear active. Their integument is hydrophobic; they float in water and are able to withstand immersion. They have been observed on rocks in streamways, where if washed off they simply floated downstream until regaining *terra firma*. Symphylans have been seen actively roaming mudbanks in JF36, in a passage which only a few hours previously was submerged.

The taxonomy of Australian symphylids has been neglected, that of Tasmanian symphylids in particular (Rushton 1990). Two genera are apparently represented in Tasmania, *Hanseniella* and *Scutigeralla*, but several undescribed species exist.

Symphylans are preadapted to subterranean life; they are blind, depigmented and normally dwell in edaphic habitats. No troglobitic Symphyla are yet known according to Scheller (1986). Since the whole group is troglomorphic it is difficult to distinguish a true cave inhabitant from one that is not. Tasmanian cave Symphyla are well suited to life underground, inhabiting the deep cave zone with other species of troglobites. Symphyla are abundant in some caves.

<u>Distribution Records for Symphyla</u>
Cracroft: Judds Cavern (C1)
Eugenana: Sherrils Cave (E201)
Franklin River: Kutikina Cave (F34),
Ida Bay: Arthurs Folly (IB110), Dismal Hill Pot (IB130), Loons Cave (IB2), Bradley Chestermans Cave (IB4)
Junee-Florentine: Cashions Creek Cave (JF6), Cauldron Pot (JF2), Gormenghast (JF35), Growling Swallet (JF36), Pendant Pot (JF37), Serendipity (JF344), Rift Cave (JF34), Tassy Pot (JF223), Junee Cave (JF8), Khazad Dum (JF4)
Mole Creek: Kubla Khan (MC1)
Mount Anne: Annakananda (MA4), cave (MA18)
Mount Ronald Cross: Capricorn Cave (MR204)
Precipitous Bluff: Bauhaus (PB6), Cueva Blanca (PB4), Quetzalcoatl Conduit (PB3), Damper Cave (PB1)
Vanishing Falls: Salisbury River Cave

2.6.6 Class Insecta
Sub-Class Diplura

Campodeid diplurans are very rare in Tasmanian caves, although they occur in caves of Europe and North America (Ferguson 1981; Vandel 1965). There are only two records to date, both from northern Tasmania. At Flowery Gully a single specimen attributed to ?*Campodea* sp. was found in the dark zone of a cave (FG201). The same form was also collected from a rotting log in pasture near the cave entrance. Of more significance is the finding of apparently troglomorphic campodeids well into the deep zone of a cave (MC13) at Mole Creek. The few specimens located were found near organic litter on riparian sediment banks.

Distribution Records for Diplura

?*Campodea* sp. (Ac/Tx?)

Flowery Gully: Flowery Gully Cave (FG201).

?*Campodea* sp. (Tb?) Mole Creek: Croesus Cave (MC13).

Collembola

The first cave Collembola records in Tasmania were from Goede *et al.* (1973b), who recorded a troglophilic *Hypogastrura* sp. and a possibly troglobitic *Adelphoderia* sp. from JF6. A paronellid was reported from L4, in addition to further unidentified material from MC75 and H-x6.

Collembola recorded from Tasmanian caves consist of 21 genera in 10 families. The genera are *Australonura, Anurida, Ceratophysella, Tullbergia, Mesaphorura, Onychiurus, Cryptopygus, Isotoma, Pseudosinella, Lepidocyrtus, Lepidophorella, Sinella, Oncopodura, Adelphoderia, Arrhopalites, Neelides, Megalothorax, Hypogastrura, Xenylla, Entomobrya* and a new genus in the family Neanuridae. The majority of taxa are adventitious or facultative cavernicoles, but troglobites are present in the Sminthuridae (*Adelphoderia*) and Paronellidae. Many species are also found in soil, leaf litter and humus, such as *Sinella, Oncopodura, Arrhopalites, Neelides* and *Megalothorax.*

Collembola may be found in a variety of subsurface habitats. Many species are deep soil and litter dwellers. In caves they may be found from the entrance zone to the deep cave zone.. Many cave occurrences are clearly adventitious species, found in logs, litter or other organic deposits, often near entrances. They can be found in the dark zone, on the surface of pools or seepages of water, sediment banks, tree roots, wet rocks in the splash zone of high energy streamways and on fungal apothecia (Eberhard 1988b).

The sminthurid genus *Adelphoderia* of the subfamily Spinothecinae is reviewed by Greenslade (1982). The subfamily has a cool temperate southern distribution, the four described species occurring in *Nothofagus* forests in Victoria and Tasmania, New Zealand and South America. *Adelphoderia* species are recorded from at least six Tasmanian karst areas. Specimens which are white, yellow or orange are probably troglobites (P. Greenslade pers. comm.). A completely eyeless troglobitic form inhabits riparian siltbanks in MC1, where it occurs in relative abundance. Another possibly troglobitic form is known from JF6. Other cave adapted forms occur in karst areas of New South Wales and Victoria (Bungonia, Jenolan, Wombeyan, Buchan) (P. Greenslade pers. comm.).

The Spinothecinae have several characters in common with the Katiannini, and overall the group shows closest relationships with *Arrhopalites*, a genus with many cave dwelling representatives elsewhere in the World (Greenslade 1982).

A new endemic genus and species of troglobite occurs in the Troglopetini (Paronellidae) (P. Greenslade pers. comm.). It is known only from IB110. Another species in the same genus is troglophilic, known from caves L3, L4, MC1 and PB6; non-troglodytic representatives occur in rainforest leaf litter, humus and soil.

The neanurid genus *Australonura* has recently been revised by Greenslade & Deharveng (1990). Another neanurid is *Anurida* sp., collected from FG201. The genus is apparently very rare in Australia, and the species recorded here is possibly restricted to caves (P. Greenslade pers. comm.).

Oncopodura is a recurrent cave dwelling genus, possibly cave adapted. The cave material is very similar to a congener which is fairly common in Tasmanian rainforest, where it occurs in moss, humus and leaf litter on the ground (P. Greenslade pers. comm.). A different species in this genus has been collected from Jenolan Caves in New South Wales.

Distribution Records for Collembola

Neanuridae

Gen. *et* sp. n.

Ile du Golfe: Cave 1 (IG-x1), Cave 4 (IG-x4)

Neanurinae

***Australonura* sp.**

Junee-Florentine: Growling Swallet (JF36)

***Australonura wellingtonia* (Womersley)**

Bubs Hill: Thylacine Lair (BH203), cave (BH19)

***Australonura* sp. c.f. *wellingtonia* gp.**

Nicholls Range: Bill Nielson Cave (NR1)

Lobellini sp.

Franklin River: Proina Cave (F51)

Pseudachorutini sp.

Mount Ronald Cross: Capricorn Cave (MR204)

Uchidanurinae

Megalanura tasmaniae
Junee-Florentine: surface
Anuridinae
***Anurida* sp.**
Flowery Gully: Flowery Gully Cave (FG201)
Hypogastruridae
Hypogastrura (Ceratophysella) ?denticulata
Junee-Florentine: Cashions Creek Cave (JF6)
***Hypogastrura purpurescens* (Lubbock)**
Bubs Hill: Fishing Pond (BH2)
Hypogastrura ?purpurescens
Lower Andrew River: Cave 1
***Ceratophysella* sp.**
Franklin River: Proina Cave (F51)
Loongana: Mostyn Hardy Cave (L4)
***Xenylla* sp.**
Ile du Golfe: Cave 4 (IG-x4)
Onychiuridae
***Tullbergia* spp.**
Acheron River: Cave 1 (IG-x1)
Franklin River: Gahnia Cave (F74), Kutikina Cave (F34)
Loongana: Leven Cave (L3)
Lower Maxwell River: "Cricket Cave" (LM-x1)
Mount Ronald Cross: Capricorn Cave (MR204)
Nicholls Range: Bill Nielson Cave (NR1), Cave 1 (NR-x1)
North Lune: Spider Den (NL3)
***Mesaphorura* sp.**
Loongana: Mostyn Hardy Cave (L4)
***Onychiurus* sp.**
Flowery Gully: Flowery Gully Cave (FG201)
Gray: Shelter Cave (G-x4)
Isotomidae
***Cryptopygus* sp.**
Mount Ronald Cross: Capricorn Cave (MR204)
Cryptopygus caecus
Mount Ronald Cross: Capricorn Cave (MR204)
Cryptopygus loftyensis
Mount Ronald Cross: Capricorn Cave (MR204)
***Isotoma (Parisotoma)* spp. ?**
Loongana: Mostyn Hardy Cave (L4)
Mount Ronald Cross: Capricorn Cave (MR204)

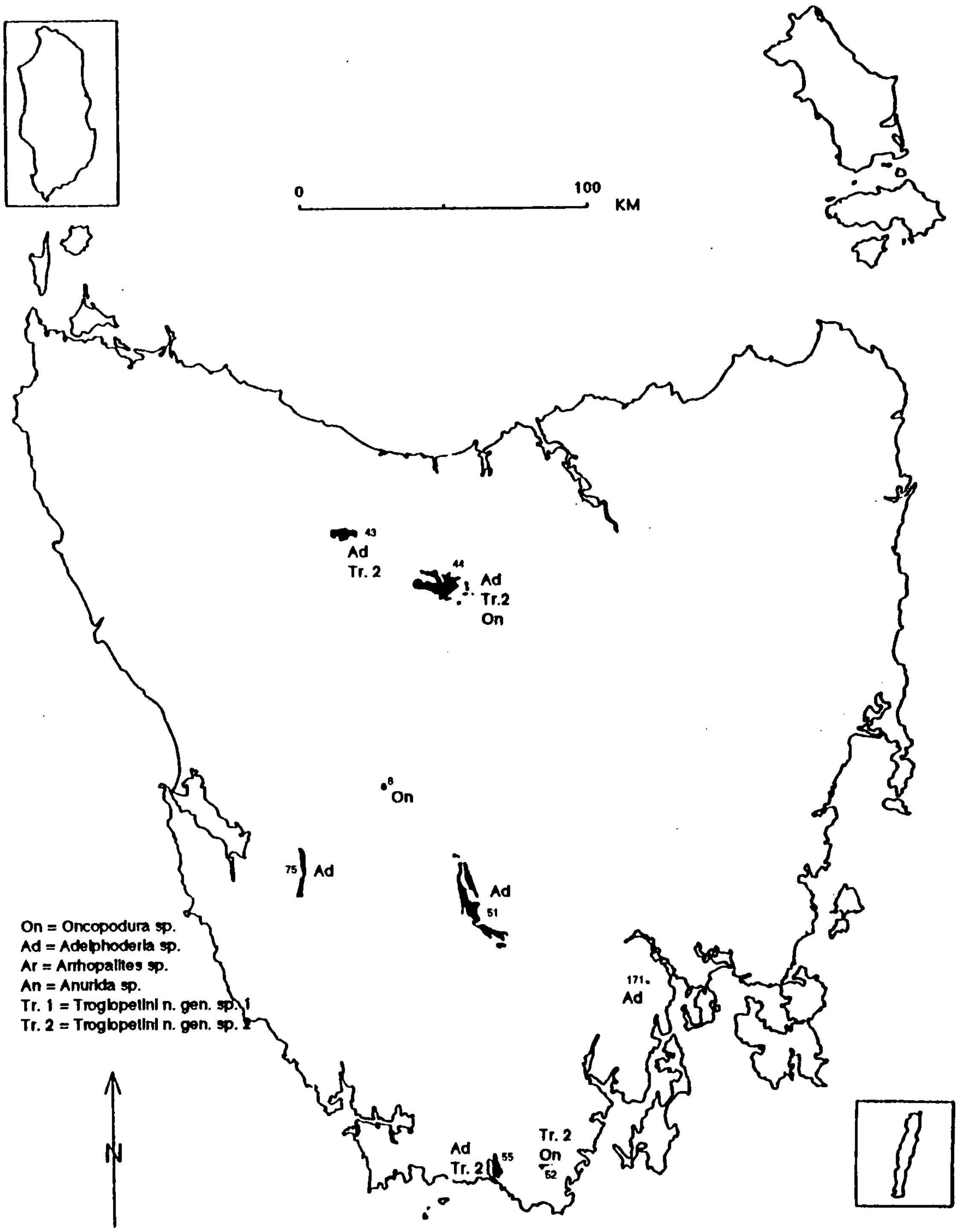


Figure 15. Cave distribution records for Collembola in the genera *Adelphoderia* and *Arrhopalites* (Sminthuridae), *Anurida* (Anuridae), *Oncopodura* (Oncopoduridae) and species in an undescribed troglopetine genus (Paronellidae).

***Isotoma (Isotoma)* sp.**
Mount Ronald Cross: Capricorn Cave (MR204)
***Folsomia candida* sp.**
Flowery Gully: surface
Entomobryidae
***Entomobrya* sp.**
Ile du Golfe: Cave 1 (IG-x1)
***Pseudosinella* sp.**
Eugenana: Sherrils Cave (E201)
***Lepidocyrtus* spp.?**
Bubs Hill: cave (BH19), cave (BH7)
Franklin River: Proina Cave (F51)
Mount Wellington: Cave 2 (WE-x2)
***Sinella* sp.**
Junee-Florentine: Cauldron Pot (JF2)
Entomobryidae sp. indet. (Tb)
Vanishing Falls: Salisbury River Cave
Paronellidae
Troglopetini n. gen. sp. 1 (Tb)
Ida Bay: Arthurs Folly Cave (IB110)
Troglopetini n. gen. sp. 2 (Tp)
Flowery Gully: Flowery Gully Cave (FG201)
Loongana: Mostyn Hardy Cave (L4), Leven Cave (L3)
Precipitous Bluff: Bauhaus (PB6)
Mole Creek: Kubla Khan (MC1), Genghis Khan (MC38)
Paronellides* sp. c.f. *dandenongensis
Junee-Florentine: surface
Oncopoduridae
***Oncopodura* sp.**
Ida Bay: Mystery Creek Cave (IB10)
Mole Creek: Kubla Khan (MC1)
Mount Ronald Cross: Capricorn Cave (MR204)
Oncopoduridae sp. indet. (Tb)
Vanishing Falls: Salisbury River Cave(Tb & Tp)
Sminthuridae
***Adelphoderia* spp. (includes troglobites)**
Franklin River: Proina Cave (F51)
Junee-Florentine: Cashions Creeek Cave (JF6)
Loongana: Leven Cave (L3)
Mole Creek: Kellys Pot (MC207), Kubla Khan (MC1) (Tb)
Mount Wellington: Cave 2 (WE-x2)
Precipitous Bluff: Bauhaus (PB6)

Flowery Gully: Flowery Gully Cave (FG201)
Neelidae
***Neelides* sp.**
Ida Bay: Loons Cave (IB2)
Loongana: Mostyn Hardy Cave (L4)
***Megalothorax* sp.**
Loongana: Mostyn Hardy cave (L4)
Tomoceridae
***Novacerus* sp.**
Mount Anne: cave (MA18) (Ac)
Novacerus* sp. c.f. *tasmanicus
Acheron River: Cave 1 (AR-x1)
***Lepidophorella* sp.**
Bubs Hill: cave (BH5)

Thysanura
There is a single cave record, considered to be adventitious, of a thysanuran in Tasmania. Clarke (1989a) reports *Ctenolepisma* sp. (Lepismatidae) from the transition zone of BH203.

Ephemeroptera
Mayflies (Ephemeroptera) are common in Tasmanian cave streams. They are adventitious cavernicoles. Nymphs may be found in large numbers in both small and large streamways. They may be swept in from an epigean source, or they may actively migrate upstream into resurgence caves. Nevertheless, they are usually found close to the entrance, or where there is plentiful input of organic litter. Adults are recorded occasionally. *Atalonella* sp. (Leptophebiidae) nymphs and adults are recorded from BH202 and BH203 (Clarke1989a), as well as IB10.

Distribution Records for Ephemeroptera
***Atalonella* sp. (Leptophebiidae)**
Bubs Hill: Minimoria (BH202), Thylacine Lair (BH203) (Clarke 1989a)
Ida Bay: Mystery Creek Cave (IB10)
Ephemeroptera spp.
Bubs Hill: Minimoria (BH202)
Gray: Elephant Farm Cave (G-x2)
Gunns Plains: Gunns Plains Tourist Cave (GP1)
Ida Bay: Mystery Creek Cave (IB10)
Junee-Florentine: Khazad Dum (JF4)
Loongana: Mostyn Hardy Cave (L4)
Lower Andrew River: Cave 1 (LA-x1), Cave 2 (LA-x2)
Nelson River: Central Cave (N-x2)

Nicholls Range: Bill Nielson Cave (NR1)
Precipitous Bluff: Damper Cave (PB1)
Vanishing Falls: Salisbury River Cave

Odonata

Clarke (1989a) reports an aeschnid exuvium, *Austroaeschna hardyi* from BH5.

Plecoptera

Where Plecoptera occur in surface streams which enter or exit from caves, they may also be found underground. They may be swept in by active sinking streams, or possibly migrate upstream into caves. Eustheniid stoneflies are reasonably abundant in Growling Swallet (JF36), Nelson River Inflow Cave (N-x1) and Mystery Creek Cave (IB10), all of which are large and powerful sinking streams. In JF36, the animals are found in the first 100m or so passage, immediately below the entrance cascades, and penetrating into the dark zone. Nymphal exuviae are common on the walls, and emergent adults have been collected also.

Distribution Records for Plecoptera

Eustheniidae

Eusthenia spectabilis

Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)
Junee-Florentine: Growling Swallet (JF36) (Goede 1967)

Possibly *Eusthenia costalis*

Bubs Hill: Minimoria (BH202) (Clarke 1989a)

Eustheniidae sp. or spp.

Junee-Florentine: Growling Swallet (JF36)
Nelson River: Nelson River Inflow Cave (N-x1)
Risbys Basin: Ray Bender's Cave

Notonemouridae

Austrocercella christinae

Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)

Plecoptera sp.

Junee-Florentine: Khazad Dum (JF4)

Orthoptera

The Orthoptera are represented in Tasmanian caves by the family Rhaphidophoridae. This family contains the majority of cavernicolous Orthoptera known in the world (Vandel 1965). They are a hygrophilic group of omnivorous scavengers. Cavernicolous species are distributed in tropical countries, particularly Asia, as well as the holarctic region and southern areas of the world including South Africa, New Zealand and Australia (Vandel 1965).

Commonly known as cave crickets, rhaphidophorids are widespread in Tasmanian caves. They also occur in granite caves, mine adits and on the surface. So far, the State's rhaphidophorid fauna comprises thirteen species in four genera: *Micropathus, Parvotettix, Cavernotettix* and *Tasmanoplectron* (Richards,1969; 1971a; 1971b; 1974). The last genus is represented by the single species, *T. isolatum,* with New Zealand affinities. It is not recorded from caves, but has a restricted distribution on Tasman Island and the Tasman Peninsula.

Cavernotettix is a south-east Australian mainland genus which occurs on the Furneaux Islands, but not Tasmania itself. *C. flindersensis* is known from caves on Flinders Island, and has also been collected from Little Dog Island and Babel Island (Richards 1967b; 1974). *C. craggiensis* occurs on Craggy Island in the Furneaux Group.

The genus *Parvotettix* is endemic to Tasmania and islands in Bass Strait. Six species are known which occur regularly in epigean as well as hypogean habitats. *P. rangaensis* is known from Ranga Cave (RA-x1) on Flinders Island (Richards 1969). *P. whinrayi* lives in caves and under boulders on islands in the Kent Group (Richards 1974). *P. fortescuensis* occurs under logs, stones and in mine tunnels in south-east Tasmania (Richards 1974). *P. domesticus* is an epigean species recorded from suburbia in Hobart (Richards 1969, 1974). *P. maydenaensis* is known from caves and rain forest in the Junee-Florentine karst area, from under logs on the Huon River (Richards 1971a, 1974), and from a cave (BH203) at Bubs Hill (Clarke 1989a). *P. goedei* is the most widely distributed, its range extending from north-west to north-east Tasmania; it is recorded from caves and mines (Richards 1969). This survey has identified a further six cave and non-cave sites where the genus *Parvotettix* is known to occur. Previously thought to be mainly confined to the drier, eastern half of Tasmania (Richards 1971a) the distribution of the genus is now extended to include western regions (Bubs Hill and Franklin River).

<u>New Distribution Records for *Parvotettix* spp.</u>

Parvotettix maydenaensis

Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)

***Parvotettix* sp.**

Flowery Gully: surface near FG201
Franklin River: Gahnia Cave (F74), surface near Vera Creek
Gunns Plains: surface near GP1
Loongana: Leven Cave (L3) (Matthews 1985)
North Lune: Spider Den (NL3)
Redpa: Glue Passage Cave (R202)
Trowutta: Trowutta Arch (T201)

Micropathus is most common in the moister western and southern parts of Tasmania, where it is established in large colonies in karst caves, pseudokarst caves and mine adits (Richards 1971a). Isolated occurrences have been recorded from surface habitats, but it is primarily a subterranean genus which is endemic to Tasmania. There are five described species, with at least one undescribed species known from the Maxwell River region (Eberhard 1987a). *M. fuscus* is established in caves in north-west Tasmania (Gunns Plains, Loongana, Trowutta) (Richards 1968b). *M. cavernicola* has a distribution extending through northern (Mole Creek, Loongana) and central-western Tasmania (Nelson River, Franklin River, Bubs Hill, Dante Rivulet, Bird River, Cheyne Range, Acheron River). *M. montanus* has a restricted distributional range in central-western Tasmania (Mount Ronald Cross, Nicholls Range, Gordon-Sprent, Franklin River). *M. tasmaniensis* is widely distributed in southern karst areas. *M. kiernani* is known from a sandstone cave near Francistown, south-east Tasmania (Richards 1974).

This survey, and those of Eberhard (1987a, 1988a, 1989), have confirmed an additional fourteen karst areas where *Micropathus* spp. occurs. More than one species of *Micropathus* may be found in any one karst area, although each species appears to occupy different caves. The distributions of species of crickets in the genus *Micropathus* are known to coincide at Loongana (Goede 1972), Franklin River (Kiernan 1982b), Mount Ronald Cross (Richards 1971a), Gordon-Sprent (Middleton 1979) and Scotts Peak (Goede pers. comm.). Richards (1971a) has suggested that the distribution and derivation of species-complexes in *Micropathus* has been influenced by Pleistocene glaciation.

New Distribution Records for *Micropathus* spp.

Micropathus cavernicola

Acheron River: Cardia Cave (AR-x2) (Eberhard 1988a)
Bubs Hill: Main Drain (BH8), 1935 Cave (BH4) (Eberhard 1987a)
Cheyne Range: cave (CR-x1) (Eberhard 1987a)
Franklin River: Deenareena Cave (F66) (Kiernan 1982b)
Gordon-Sprent: unidentified cave (Middleton 1979)
Lower Andrew River: Cave 1 (LA-x1), Cave 2 (LA-x2) (Eberhard 1988a)
Nelson River: Central Cave (N-x2)

Micropathus montanus

Franklin River: Kutikina Cave (F34)
Gordon-Sprent: Cave 1 (GS-x1), Cave 2 (GS-x2), Cave 3 (GS-x3) (Eberhard 1987a)
Nicholls Range: Bill Nielson Cave (NR1), surface (Eberhard1987a)

Micropathus ?fuscus

Savage River: Ferncliff Cave (SR-x1)

Micropathus tasmaniensis

Davey River: Cave 2 (DV-x2) (Eberhard 1989)

Jubilee Ridge: Jubilee Ridge Cave (JB-x1)
North Lune: Spider Den (NL3) (Clarke 1990)
Louisa Bay: Louisa Bay Caves (A. Green pers. comm.)
***Micropathus* sp. n. (close to *M. montanus*)**
Lower Maxwell River (& possibly West Maxwell-Algonkian): Ballawinne Cave (LM-x4), "Cricket Cave" (LM-x1), Cave M8604 (LM-x2), Cave M8605 (LM-x3) (Eberhard 1987a, 1988a)
***Micropathus* spp.**
Mount Weld: Arrakis (MW-x1)
Risbys Basin: Ray Bender's Cave
Upper Weld River: Keyhole Cavern
Vanishing Falls: Salisbury River Cave and others
West Maxwell-Algonkian: unidentified caves

Psocoptera

Psocids were first reported from Tasmanian caves by Terauds (1973), probably from caves at Mole Creek. These minute animals are easily overlooked. A troglomorphic psocid is known from a small cave (E201) at Eugenana, which is a small and isolated limestone outcrop in northern Tasmania. The only cave known here is surrounded by pasture and rural development. The cave specimens have relatively long antennae. If it is a troglobitic species, or a cave-isolated population, it must be considered vulnerable.

Cavernicolous Psocoptera have been reported elsewhere from Europe, Africa and the United States (Vandel 1965).

Hemiptera

Hemipteran groups recorded from Tasmanian caves include Enicocephalidae, Aphididae, Fulgoroidea, Cercopoidea, Veliidae, Mesoveliidae, Notonectidae and ?Cicadelloidea. The first three groups are the most interesting from a biospeleological point of view. The latter are all accidental cavernicoles.

Enicocephalidae

Of some interest is the discovery of troglobitic enicocephalid bugs, from two separate localities in northern Tasmania. These small animals display troglomorphic characters including reduced eyes and relatively long setae. Both were collected from flood litter or wood in the dark zone of stream caves at Mole Creek and Loongana respectively.

<u>Distribution Records for Enicocephalidae</u>

Enicocephalidae sp. or spp. (Tb)
Loongana: Mostyn Hardy Cave (L4)

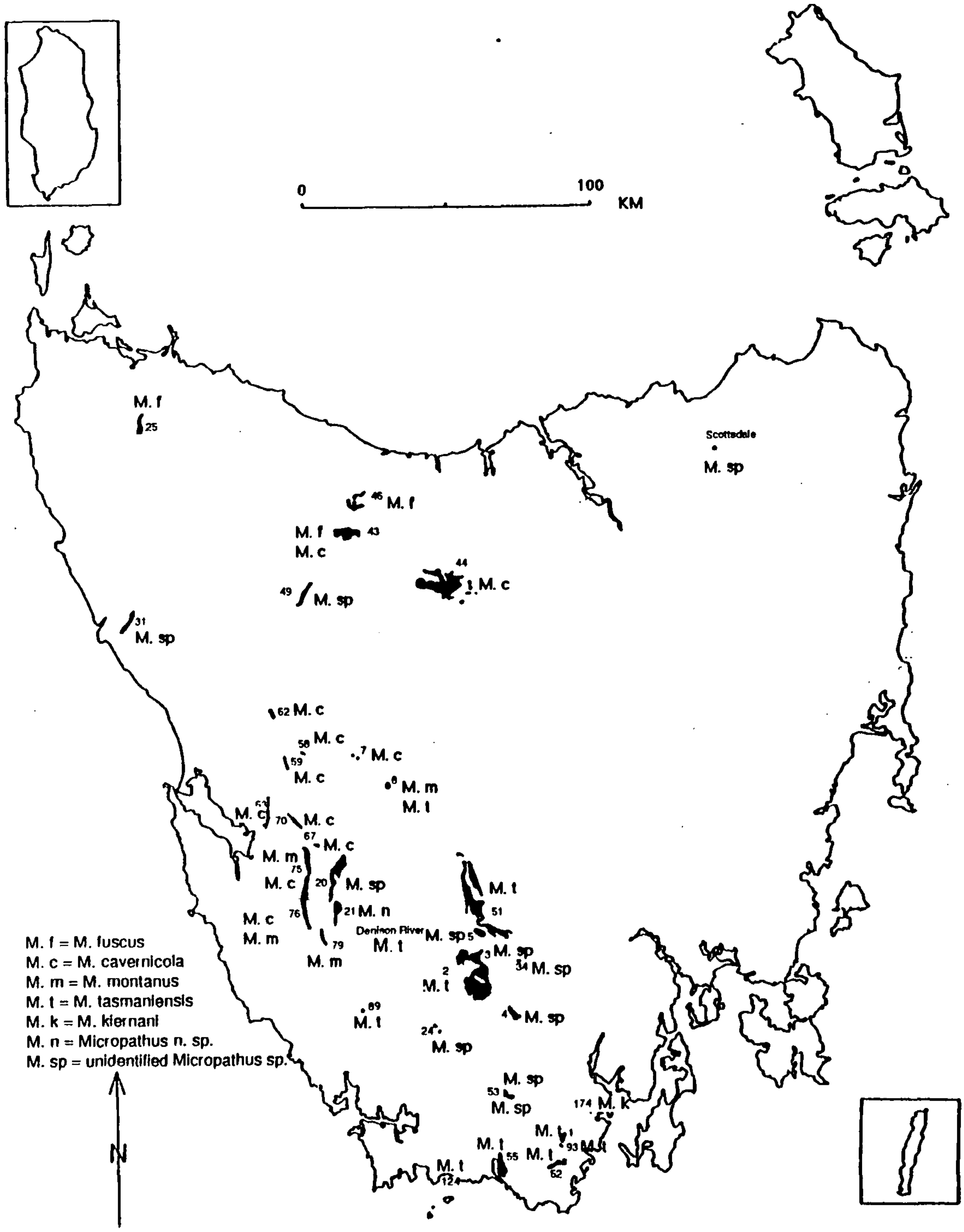


Figure 16. Distribution records for crickets in the genus *Micropathus*.

Mole Creek: Kellys Pot (MC207)

Aphididae

Clarke (1989a) first reported the subterranean occurrence of aphids in Tasmania. In this case, an introduced species *Myzus persicae* was collected from roots in the twilight zone of BH19. Aphids have also been found on, and near, tree roots in Kubla Khan (MC1) and Genghis Khan Caves (MC39). Both adults and nymphs were present, the nymphs being found only on the roots whilst adults occurred on roots and nearby substrates. They appear to be a specialised root fauna.

Distribution Records for Aphididae

Myzus persicae

Bubs Hill: cave (BH19) (Clarke 1989)

Aphididae sp.

Mole Creek: Kubla Khan (MC1), Genghis Khan (MC39)

Fulgoroidea and Cercopoidea

Cave dwelling planthoppers (Fulgoroidea) and spittle bugs (Cercopoidea) have been recorded from Tasmanian caves only recently (Eberhard 1990a). The adults and nymphs are usually found in association with tree roots. The material collected so far appears to be of facultative cave species. This discovery is of some consequence in relation to recent work in North Queensland caves where a rich and highly interesting assemblage of cave-dwelling planthoppers has been found (Hoche & Asche 1988). The Queensland species are extremely cave adapted and also specialise on tree root-feeding.

Distribution Records for Fulgoroidea and Cercopoidea (Tp/Tx?)

Cracroft: cave (C-x2)

Ida Bay: Bradley Chestermans Cave (IB4)

Mole Creek: Genghis Khan (MC39), Little Trimmer (MC38).

Other Hemiptera

All other hemipteran groups recorded from caves are accidental or adventitious cavernicoles. They include water boatmen (Notonectidae), pond skaters or water striders (Veliidae & Mesoveliidae) and Cicadelloidea.

Distribution Records for Other Hemiptera

Notonectidae

Gunns Plains: Gunns Plains Tourist Cave (GP1)

Veliidae

***Microvelia* sp. or *Rhagovelia* sp.**

Nelson River: Central Cave (N-x2)

Mesoveliidae
***?Mesovelia* sp.**
Loongana: Mostyn Hardy Cave (L4)
Unidentified Water Strider
Trowutta: Trowutta Arch (T201)
?Cicadelloidea
Loongana: Mostyn Hardy Cave (L4)
Nicholls Range: Bill Nielson Cave (NR1)
Hemiptera spp.
Ida Bay: Great Expectations Cave (IB129)
Junee-Florentine: Khazad Dum (JF4)
Lower Andrew River: Cave 1 (LA-x1), Cave 2 (LA-x2)
Lower Maxwell River: "Cricket" Cave (LM-x1)

Neuroptera

Unidentified Neuroptera are recorded from two large stream caves, IB14 (Richards & Ollier 1976) and JF36; and a shelter cave (M186) in the Maxwell River area. They are adventitious cavernicoles.

Coleoptera

Tasmanian caves have a distinctive and highly interesting cave beetle fauna. Troglobites in the family Carabidae, tribes Trechini and Zolini, are represented.

The Trechini is a large group, with hygrophilous and geophilous habits, which is largely confined to the temperate regions of both hemispheres. In an Australian context all the most plesiomorphic species (notably those in the genus *Tasmanorites*) are today confined to Tasmania, whilst a large portion of the most derived species (e.g. *Trechimorphus diemenensis*) are Australian mainland insects (Moore 1972a). Trechines are dominant elements in the cave faunas of North America, Europe and Japan (Vandel 1965), as well as New Zealand (May 1963).

In Tasmania, troglobitic trechines are represented in the genera *Tasmanotrechus* and *Goedetrechus*. The troglophilic *Tasmanorites elegans* Moore was first described from material collected in Bottomless Pit (G-x1). Likewise, *Tasmanorites flavipes* (Lea) was first described from specimens collected in the Ida Bay Caves, but it has subsequently been collected from riparian surface habitats at Arve River and the Florentine Valley. A new species of *Tasmanorites* has been collected from a cave at Bubs Hill (Clarke 1989a).

Tasmanotrechus cockerilli is a troglobite from the Mole Creek caves. Two other congeners, *T. leai* and *T. concolor*, have been described by Moore (1972a) in addition to other undescribed cavernicolous forms. *Goedetrechus mendumae* and

G. parallelus are troglobites from Ida Bay and the Florentine Valley respectively. The latter species has vestigial eyes and the former has lost all trace of eyes. A third congener with vestigial eyes, *G. talpinus*, is endogeous (soil and humus dweller) and known from Blue Tier in north-east Tasmania.

Trechine troglobites are generally very rare in any given cave. Many collections are represented by single specimens only. They are confined mostly to the deep cave zone, where they are found under stones, in or near flood litter on riparian siltbanks, on moist substrates near water, or near seepages. Larvae are found on flood-prone siltbanks beside streams. They may also be found occasionally some distance from permanent water, such as the dry flowstone surfaces of Dulcimer Chamber in the upper levels of Kubla Khan Cave (MC1).

The other important group of Tasmanian cave dwelling beetles is the Zolini which is confined to Australasia. Locally endemic troglobitic species of *Idacarabus* occur at Hastings, Ida Bay, and Precipitous Bluff. A possible fourth species has been collected from a cave at Mole Creek (MC52) (Moore 1978), and further undescribed material is known from Mount Ronald Cross (MR204), Mount Anne (MA1, MA10) and Vanishing Falls. *Pterocyrtus* is the genus inhabiting the caves along the Gordon and Franklin Rivers. *P. striatulus* was initially described from material collected in Bottomless Pit (G-x1) (Sloane 1920).

Zolines are generally more abundant than trechines. They are not as highly troglomorphic, and are not generally restricted to riparian type habitats. They may be found on siltbanks, walls, roof and floor and may be found quite close to entrances, including the twilight zone.

The relictual genus *Idacarabus* is exclusively troglobitic. Species within this genus are found only in the alpine and montane impounded fluviokarsts of southern Tasmania (Kiernan & Eberhard in press). *Idacarabus troglodytes* is restricted to the Ida Bay karst, whilst *I. cordicollis* and *I. longicollis* occur at Hastings and Precipitous Bluff respectively.

Collections from Tasmanian caves have revealed new species of both trechine (including *Tasmanotrechus* spp.) and zoline beetles. Unfortunately, this highly interesting material remains undescribed. These beetles are cryptic and very rare. Distribution ranges are highly restricted and population numbers probably low. Some species appear to be limited to a single cave, while closely related sister-species occupy nearby caves, still within the same hydrologic system. At least two species of trechine troglobite are known in MC1.

The disjunct distribution patterns seen in Tasmania's carabid cave beetles closely parallel those seen in the northern hemisphere. The general characteristics of the Australasian cave beetle fauna are in keeping with the concept of a Pleistocene derivation for troglobites, as has been invoked for northern hemisphere cave beetle faunas (Moore 1972b). Aspects of the evolutionary history of the Tasmanian cave beetles, and other troglobitic species, is discussed more fully later.

Other beetle groups recorded from caves include Pselaphidae, Tenebrionidae, Lucanidae, Curculionidae, Scydmaenidae, Phalacridae, Staphylinidae, Dascillidae, Elateridae, Cerambycidae, Hydrophiloidea, Melyridae, Byrrhidae, Gyriniidae, ?Scarabaeidae and other Carabidae. Most of these are accidentals, typically associated with litter deposits near entrances. At Bubs Hill, Clarke (1989a) recorded accidental species from the families Scydmaenidae, Phalacridae, Lucanidae, Pselaphidae, Melyridae, Byrrhidae, Curculionidae and Gyrinidae. Pselaphids, however, have been found in flood litter and near tree roots in the dark zone. In other parts of the world, troglobitic forms occur (Vandel 1965). There are recurrent records of staphylinids in Tasmanian caves. They are found in dry passages, under stones or organic matter, but usually not far from the surface.

Distribution Records for Trechini

Goedetrechus mendumae **(Tb)**
Ida Bay: Exit Cave (IB14) (type locality) (Moore 1972a)

Goedetrechus parallelus **(Tb)**
Junee-Florentine: Cashions Creek Cave (JF6) (type locality), Frankcombe Cave (JF7) (Moore 1972a), Growling Swallet (JF36)

Goedetrechus talpinus **(Ed)**
Blue Tier: endogeous (Moore 1972a)

?*Goedetrechus* sp.
Junee-Florentine: Deviation Cave (JF55) (Matthews 1985), Pendant Pot (JF37), "Wherrets" Cave (JF-x6), Cauldron Pot (JF2), Threefortyone (JF341)

Tasmanotrechus cockerilli **(Tb)**
Mole Creek: Georgies Hall Cave (MC201) (type locality), Scotts Cave (MC52), Baldocks Cave (MC32), Herberts Pot (MC202) (Moore 1972a)

Tasmanotrechus **sp. n. A (near *T. leai*) (Tp)**
Bubs Hill: caves BH5, BH13 & BH203 (Clarke 1989a)

Tasmanotrechus **sp. n. A-1 (near *T. leai*) (Tp)**
Bubs Hill: cave BH16 (Clarke 1989)

Tasmanotrechus **sp. n. B (Tb)**
Bubs Hill: Minimoria (BH202); cave (BH3) (Clarke 1989a)

Tasmanotrechus **sp. (near *T.* sp. n. B) (Tb)**
Mount Anne: Deep Thought (MA10), Col-In-Cavern (MA1)

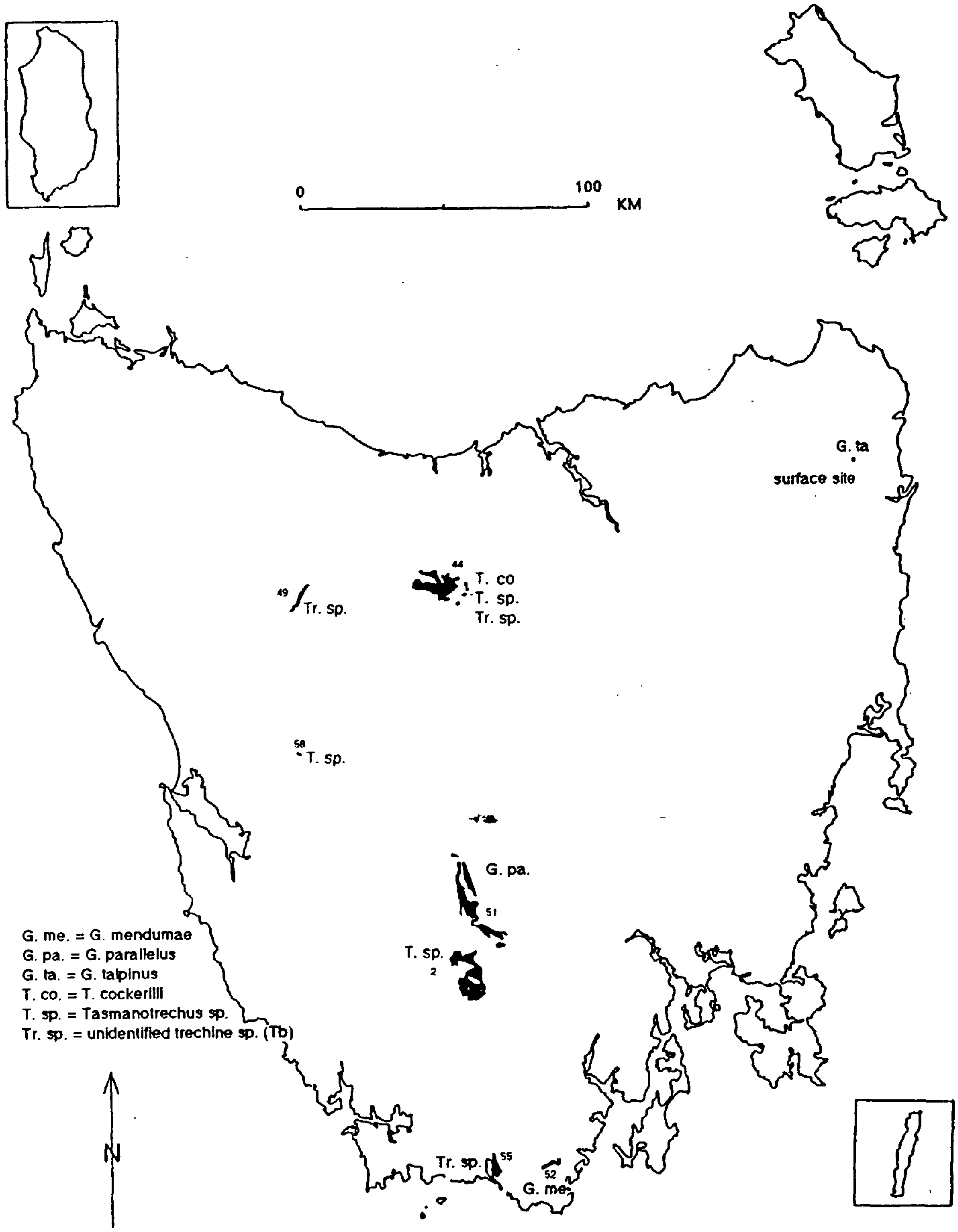


Figure 17. Distribution records for trechine beetles in the genera *Goedetrechus* and *Tasmanotrechus*.

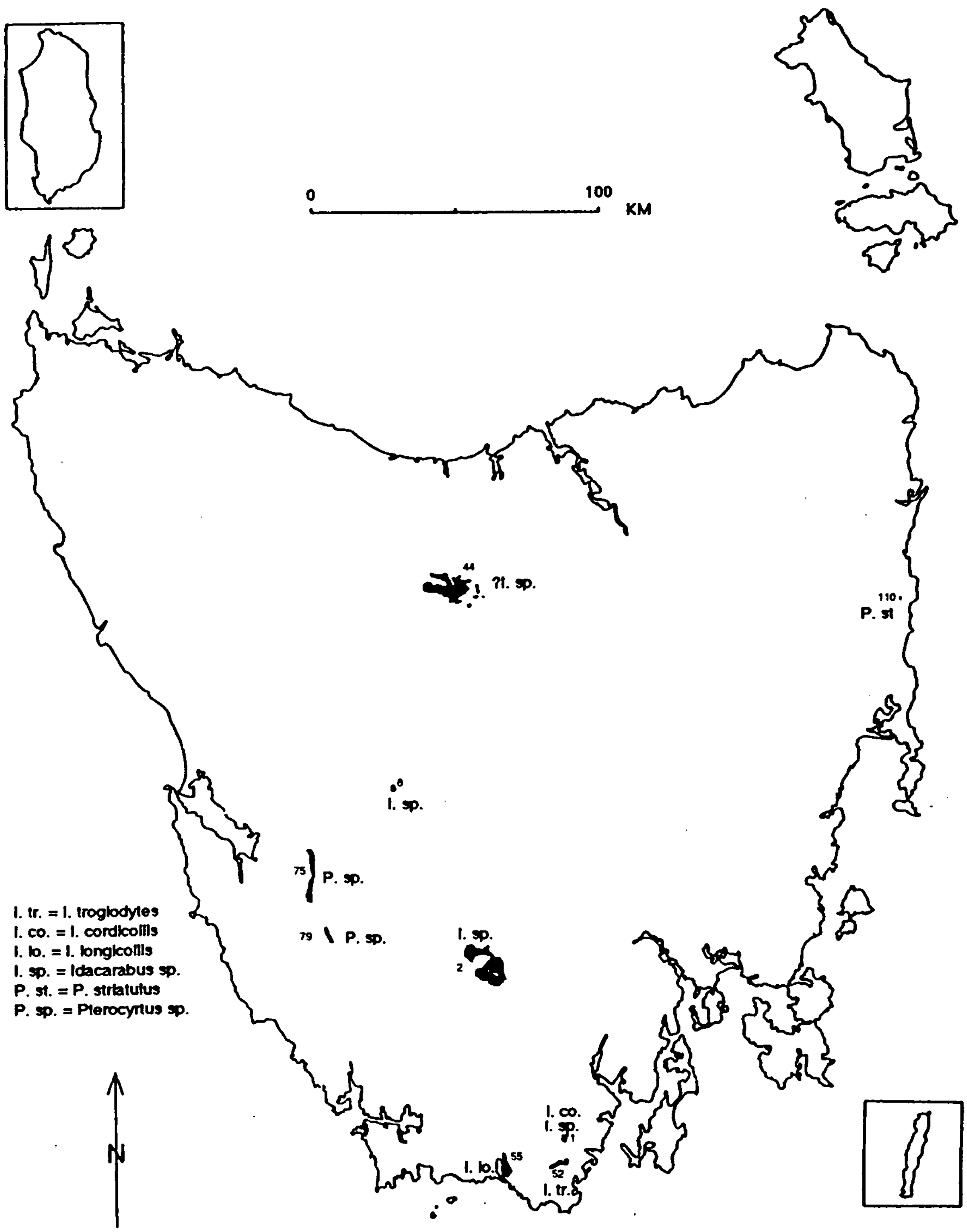


Figure 18. Cave distribution records for zoline beetles in the genera *Idacarabus* and *Pterocyrtus*.

Tasmanotrechus **sp. n. C (Tb)**
Mole Creek: Kellys Pot (MC207)
Tasmanorites flavipes **(Lea) (Ac?)**
Ida Bay: Mystery Creek Cave (IB10) (type locality) (Moore 1972a)
Tasmanorites elegans **(Ac?)**
Gray: Bottomless Pit (G-x1) (Moore 1972a)
Trechini spp. indet. (inc. Tbs)
Gray: Elephant Farm Cave (G-x2), Rum Pot (G-x3)
Junee-Florentine: Growling Swallet (JF36), Asteroid Pot (JF366), Khazad Dum (JF4)
Mole Creek: Little Trimmer Cave (MC38), Kubla Khan (MC1), Genghis Khan (MC39)
Mount Cripps: Philrod Cave (CR3)
Precipitous Bluff: Damper Cave (PB1)
Risbys Basin: Ray Bender's Cave

Distribution Records for Zolini
Idacarabus troglodytes **(Tb)**
Ida Bay: Mystery Creek Cave (IB10) (type locality), Exit Cave (IB14), Revelation Cave (IB1); plus other caves (ref. Eberhard1990)
Idacarabus longicollis **(Tb)**
Precipitous Bluff: Damper Cave (PB1) (type locality)
Idacarabus ?longicollis **(Tb)**
Precipitous Bluff: Bauhaus (PB6), cave (PB13)
Idacarabus cordicollis **(Tb)**
Hastings: Newdegate Cave (H-x7) (type locality), King George V Cave (H-x6)
Idacarabus **sp. n. A (Tb)**
Hastings: Trafalgar Pot (H207)
Idacarabus **sp. n. B (Tb?)**
Mount Anne: cave (MA18)
Idacarabus **sp. n. C (Tb)**
Mount Ronald Cross: Capricorn Cave (MR204)
Idacarabus **spp. (Tb)**
Hastings: Wolfe Hole (H-x8)
Mole Creek: ?Scotts Cave (Moore 1978)
Vanishing Falls: Salisbury River Cave
Pterocyrtus striatulus **(Tp?)**
Gray: Bottomless Pit (G-x1) (Sloane 1920).
Pterocyrtus **sp n. (Tb?)**
Franklin River: Kutikina Cave (F34), Deenareena Cave (F66)
Nicholls Range: Bill Nielson Cave (NR1)

Distribution Records for Other Carabidae

***Percosoma carenoides* (Ac)**
Junee-Florentine: Warhol (JF392)
***Notagonum marginellum* Er. (Ac)**
Maxwell River: cave (M-8604)
***Rhabdotus eflexus* (Ac)**
Bubs Hill: Main Drain (BH8) (Clarke 1989a)
***Stichonatus leai* (Ac)**
Bubs Hill: cave (BH16) (Clarke 1989a)

Distribution Records for Staphylinoidea

Staphylinidae spp.
Acheron River: Cardia Cave (AR-x2)
Bubs Hill: 1935 Cave (BH4), Minimoria (BH202); Thylacine Lair (BH203), caves (BH5 & BH7) (Clarke 1989a)
Eugenana: Sherrils Cave (E201)
Flowery Gully: Flowery Gully Cave (FG201)
Montagu: Main Cave (MU201)
Mount Anne: Deep Thought (MA10)
Nelson River: Central Cave (N-x2)
?Staphylinidae sp.
Nicholls Range: Bill Nielson Cave (NR1)
Staphylinoidea sp.
Hastings: King George V Cave (H-x6)

Diptera

The dipteran fauna of Tasmanian caves is not well known although it is clear that considerable diversity exists. The majority of species appear to be trogloxenes that utilise caves for temporary shelter. Families recorded in Tasmanian caves include Keroplatididae, Tipulidae, Simulidae, Culicidae, Chironomidae, Cecidomyiidae, Sciaridae, Anisopodidae, Ceratopogonidae, Calliphoridae, Phoridae, and Sphaeroceridae (Terauds 1973, Clarke 1989a). Any single cave may hold quite a diverse dipteran fauna. Clarke (1989a) for example, found 10 species in BH203.

Flies are typically found resting on walls in the entrance and twilight zones. Sometimes, swarms gather in entrances. Other flies may be found in the transition and dark zone. Fly larvae and pupae have been captured in streamways and litter deposits. Blowflies and other unidentified species are attracted to caves by food resources.

Undoubtedly, Tasmania's best known cave dwelling dipteran is the glow worm, the luminous larva of a fungus gnat, *Arachnocampa (Arachnocampa)* *tasmaniensis* (Keroplatididae). First described by Ferguson (1925), the species is endemic to Tasmania. Congeneric species occur in Victoria, New South Wales, Queensland and New Zealand (Harrison 1961). The Tasmanian species, however, is more closely related to the New Zealand species than to either of the two species on the Australian mainland (Harrison 1966). *A. tasmaniensis* is not confined to caves. It also occurs in suitably moist and sheltered surface habitats such as rainforest, mixed forest and fern gullies. It is most abundant in stream caves, where there is a plentiful food supply available. It is generally found near entrances, rarely deep inside caves, and does not occur in dry or polluted caves. It has been hypothesised that the disappearance of the glow-worm colony from Flowery Gully Cave (FG201) is a result of quarrying and land clearance activity directly above the cave and in its catchment area (Kiernan 1977). The stream feeding the cave is now intermittent and organically polluted, and the aquatic insects (such as midges, mayflies and caddis flies) which form part of the glow-worms food supply appear to be locally extinct. Further, as glow-worms are not all confined to the cave environment but may also live in the surrounding forest, it is essential that forest in the vicinity of cave entrances be preserved as a refuge for the glow-worms, thus allowing possible and continuous colonisation of the caves (Richards & Ollier 1976). Maintenance of surrounding forest and catchment integrity is important for survival of glow-worm populations. Richards (*in* Greenslade 1985) suggests conservation measures for the Tasmanian glow-worm.

No studies are available on the biology of the Tasmanian glow-worm, although the New Zealand glow-worm has received attention from Richards (1960, 1964b). Williams (1975) outlined problems experienced in the Waitomo glow-worm Caves following road building and forestry activity in the catchment area. The distribution records given below are far from complete, but give an indication of the widespread occurrence of *A. tasmaniensis*.

<u>Distribution Records for Diptera</u>

Mycetophilidae

Arachnocampa (Arachnocampa) tasmaniensis

Bird River: cave (Goede 1967)
Bubs Hill: Thylacine Lair (BH203) plus other caves (ref. Clarke 1989a)
Cracroft: Judds Cavern (C1)
Gunns Plains: Gunns Plains Tourist Cave (GP1)
Franklin River: Gahnia Cave (F74) plus other caves (ref. Middleton 1979)
Ida Bay: Exit Cave (IB14), Mystery Creek Cave (IB10), March Fly Pot (IB46), cave (IB92), cave (IB125)
Julius River: Julius River Swallet (JR2) (Kiernan 1980b)
Junee-Florentine: Cashions Creek Cave (JF6), Khazad Dum (JF4), Growling Swallet (JF36), Junee Cave (JF8) (Goede 1967)
Loongana: Mostyn Hardy Cave (L4)

Mole Creek: Kubla Khan (MC1), Marakoopa Cave (MC120), Wet Cave (MC207), Lynds Cave (MC14), Westmoreland Cave (MC-x64) (Goede 1967); Glow-Worm Cave (MC16), Georgies Hall Cave (MC201) (Matthews 1985)
Mount Anne: unidentified cave
Mount Ronald Cross: Capricorn Cave (MR204)
Nelson River: Central Cave (N-x2)
Nicholls Range: Bill Nielson Cave (NR1)
North Lune: Spider Den (NL3) (Clarke 1990)
Precipitous Bluff: Quetzalcoatl Conduit (PB3), Bauhaus (PB6)
Risbys Basin: Ray Bender's Cave
Vanishing Falls: Salisbury River Cave, Waterfall Spring Cave
West Maxwell-Algongkian: cave

Culicidae spp.

Bubs Hill: Thylacine Lair (BH203), Minimoria (BH202), cave (BH2) (Clarke 1989a)
Flowery Gully: Flowery Gully Cave (FG201)
Gunns Plains: Gunns Plains Tourist Cave (GP1)
Ida Bay: Exit Cave (IB14) (Richards & Ollier 1976)
Redpa: Glue Passage Cave (R201)

Calliphoridae sp.

Bubs Hill: Main Drain (BH8) (Clarke 1989a)
Eugenana: Sherrils Cave (E201)
Junee-Florentine: Khazad Dum (JF4)
Mole Creek: Little Trimmer Cave (MC38)

Chironomidae

Podonomopsis discoceros

Ida Bay: Exit Cave (IB14) (Richards & Ollier 1976)

***Lopescladius* SRV sp. 39**

Nicholls Range: Bill Nielson cave (NR1) (V. Pettigrove pers. comm.)

Tribe Tanytarsini

Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)

Chironomidae sp.

Bubs Hill: cave (BH13) (Clarke 1989a)

?Chironomidae

Gunns Plains: Gunns Plains Tourist cave (GP1), Weerona Cave (GP2)
Ida Bay: Loons Cave (IB2)

Simulidae sp. or spp. indet. (Ac)

Junee-Florentine: Khazad Dum (JF4)
Nicholls Range: Bill Nielson Cave (NR1)

Sciaridae

***Sciara* sp.**

Ida Bay: Exit Cave (IB14) (Richards & Ollier 1976)

spp. indet.
Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)
Tipulidae
***Limnophila* sp.**
Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)
Ida Bay: Exit Cave (IB14) (Richards & Ollier 1976)
Junee-Florentine: Cashions Creek Cave (JF6) (Goede 1967)
***Monophilus* sp.**
Mole Creek: Marakoopa Cave (MC120) (Goede 1967)
***Trichocera* sp.**
Junee-Florentine: Cashions Creek Cave (JF6) (Goede 1967)
Tipulidae spp.
Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)
Cecidomyiidae spp.
Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)
Anisopodidae
Probably *Sylvicola* sp.
Bubs Hill: cave (Clarke 1989a)
Ceratopogonidae
***Culicoides* sp.**
Bubs Hill: Main Drain (BH8) (Clarke 1989a)
Phoridae sp.
Bubs Hill: Main Drain (BH8) (Clarke 1989a)
Sphaeroceridae
***Sphaerocera* spp.**
Mole Creek: Pyramid Cave (MC3) (Terauds 1973)
Nematocera sp.
Bubs Hill: cave (BH19) (Clarke 1989a)
Diptera spp.
Acheron River: Cardia Cave (AR-x2), Cave 1 (AR-x1)
Cheyne Range: cave (CR-x1)
Cracroft: Judds Cavern (C1)
Davey River: Cave 1 (DV-x1), Cave 2 (DV-x2)
Eugenana: Sherrils Cave (E201)
Flowery Gully: Flowery Gully Cave (FG201)
Franklin River: Proina Cave (F51)
Gray: Rum Pot (G-x3)
Gunns Plains: Gunns Plains Tourist Cave (GP1), Weerona Cave (GP2)
Ida Bay: Mystery Creek Cave (IB10), Hobbit Hole (IB15), Little Grunt (IB23), Bradley Chesterman Cave (IB4), Trackcutters Cave (IB211), caves (IB51, IB90, IB93, IB97, IB104 & IB117)
Ile du Golfe: Cave 1 (IG-x1), Cave 2 (IG-x2)
Jubilee Ridge: Jubilee Ridge Cave (JB-x1)

Junee-Florentine: Growling Swallet (JF36), Porcupine Pot (JF387), Khazad Dum (JF4), Welcome Stranger (JF229), cave (JF208)
Loongana: Leven Cave (L3), Mostyn Hardy Cave (L4)
Lower Andrew River: Cave 2 (LA-x2)
Nelson River: Central Cave (N-x2)
Mole Creek: Kellys Pot (MC207)
Mount Ronald Cross: Capricorn Cave (MR204)
Mount Wellington: Cave 1 (WE-x1), Cave 2 (WE-x2)
Nicholls Range: Bill Nielson cave (NR1), Cave 1 (NR-x1)
Precipitous Bluff: Bauhaus (PB6)
Redpa: Glue Passage Cave (R202)
Risbys Basin: Ray Bender's Cave
Trowutta: Trowutta Arch (T201)
Vanishing Falls: caves

Trichoptera

Caddis flies (Trichoptera) are sometimes common in cave streamways. Like Plecoptera and Ephemeroptera, they are swept into caves by active sinking streams. Groups recorded include Calocidae, Leptoceridae, Rhyacophilidae, Philopotamidae, Hydrobiosidae and Hydropsychidae. Occasionally, caddis fly populations may be found deep underground. For instance, in Cauldron Pot (JF2) both adults and larvae of ?*Asmicridea* sp. can be found in reasonable numbers in a section of streamway which is 300m below the surface, and beyond a section of waterfalls up to 40m high. Vandel (1965) cites the case of a European species of caddis fly which completes its entire life cycle underground, although it is non-troglomorphic. There is a single record of a terrestrial caddis fly larva, *Caloca saneva,* from IB100 (Eberhard 1990a). Identifications were provided by J. Jackson.

Distribution Records for Trichoptera

Hydrobiosidae

Apsilochorema obliqua

Ida Bay: Exit Cave (IB14) (Richards & Ollier 1976)

***Taschorema* sp.**

Ida Bay: Exit Cave (IB14) (Richards & Ollier 1976)

Hydrobiosidae spp.

Bubs Hill: Thylacine Lair (BH203) (Clarke 1989a)
Gunns Plains: Gunns Plains Tourist Cave (GP1)
Lower Andrew River: Cave 1 (LA-x1), Cave 2 (LA-x2)

Philopotamidae

Hydrobiosella tasmanica

Junee-Florentine: Growling Swallet (JF36)

Hydropsychidae
?Asmicridea
Junee-Florentine: Cauldron Pot (JF2)
Hydropsychidae sp.
Gunns Plains: Gunns Plains Tourist Cave
Leptoceridae sp.
Bubs Hill: Main Drain (BH8)
Calocidae
Caloca saneva
Ida Bay: cave (IB100)
Trichoptera spp.
Acheron River: Cave 1 (AR-x1)
Junee-Florentine: Khazad Dum (JF4), Growling Swallet (JF36)
Loongana: Mostyn Hardy Cave (L4)
Nicholls Range: Bill Nielson Cave (NR1)
Trowutta: Trowutta Arch (T201)

Lepidoptera

Moths use caves for shelter. They may be found on walls in the twilight and transition zone, but rarely far from the entrance. They seem to prefer dry walls which are often associated with draughting entrances. They have also been recorded from wet leaf litter beside a streamway. They constitute part of the parietal fauna (Vandel 1965), and could also be classified as trogloxenes. Clarke (1989a), records larvae of Oecophoridae, and both larvae and pupae of Hepialidae at Bubs Hill.

Distribution Records for Lepidoptera

Oecophoridae
***Barea* sp.**
Bubs Hill: Thylacine Lair (BH203), caves (BH5 & BH16) (Clarke 1989a)
Hepialidae spp. indet.
Bubs Hill: Thylacine Lair (BH203), cave (BH5) (Clarke 1989a)
Lepidoptera spp.
Eugenana: Sherrils Cave (E201).
Flowery Gully: Flowery Gully Cave (FG201).
Mole Creek: Little Trimmer Cave (MC38).
Nicholls Range: Bill Nielson Cave (NR1).

Hymenoptera

Ants (Formicidae) have been recorded from caves on two separate occasions: an unidentified species from E201, and *Chelaner leae* (Forel) from BH1 (Clarke 1989a). They are adventitious cavernicoles and are not an important component of the State's cave fauna.

2.7 Phylum Mollusca

By far the most significant freshwater mollusc family in Tasmania, and in South Australia and Victoria, in terms of species diversity, is the Hydrobiidae (Ponder *et al.* 1988). Tasmanian caves support a rich fauna of freshwater molluscs, all material collected to date being hydrobiid gastropods. Tasmanian Hydrobiidae is a highly speciose group which typically has limited dispersal powers and restricted distributions (Ponder *et al.* 1988). There are many instances of taxa being confined to single streams or, more commonly, to a single minor drainage area. Hydrobiids are typically found in small water bodies within caves (small streams, trickles, seepages and drip pools).

All the material collected from caves so far is new. It includes both epigean forms and fully stygobiontic forms. There are four common cavernicolous genera: *Beddomeia, Phrantela, Fluvidona and "Fluviopupa"*. Many collections include more than one genus. Some, or all, of these genera may be found together at the same site, but there is a high degree of site specificity in the collections. An unusual *Beddomeia* sp. is known from a drip pool at Cracroft (C-x9). Closely related to *Beddomeia* is a highly cave adapted monospecific genus and species, *Pseudotricula eberhardi,* which is found only at Precipitous Bluff (Ponder 1992); it occurs abundantly in stream passages here. Also from Precipitous Bluff is a single specimen of another unusual hydrobiid, possibly representing a new genus and species with affinities to *Phrantela* (W. Ponder pers. comm.). Six species of cavernicolous hydrobiid are known from Precipitous Bluff, which is equal to the highest sympatric diversity of hydrobiids seen anywhere in Australia (W. Ponder pers. comm.). Other possibly cave adapted species include *Fluvidona*? n. sp. from JF8, and *Fluvidona* sp. from IB34. *Fluvidona* from Little Grunt and Exit Cave is unusual in that some of the specimens have very reduced or absent opercular pegs, and there is some variation in size and development of the operculum (W. Ponder pers. comm.).

The terrestrial molluscs so far collected include no true cavernicoles. Most of the material consists of accidental species, derived from surface litter environments. There are some exceptions however. At Flowery Gully, an adventitious species of charopid(?) and a slug have successfully invaded a cave there. In this case they are common pasture species. Perhaps the most common land snail found in caves is *Caryodes dufresni*. It is found in litter deposits or on walls near entrances. Other land snail groups recorded include Punctidae, Charopidae, Arionidae, Rhytididae and Helicarionidae.

The identifications given below were provided by Dr W. Ponder.

Distribution Records for Hydrobiidae

Phrantela **n. sp. A**
Ida Bay: Mystery Creek Cave (IB10), Loons Cave (IB2)
Phrantela **cf. sp. A**
Junee-Florentine: Rift Cave (JF34), Junee Cave (JF8)
Phrantela **aff. sp. A**
Hastings: King George V Cave (H-x6)
Phrantela **n. sp. B**
Franklin River: Gahnia Cave (F74)
Phrantela **n. sp. c.f B**
Redpa: Cow Cave (R204)
Lower Maxwell River: "Cricket" Cave (LM-x1)
Phrantela **n. sp. C**
West Maxwell-Algongkian: cave
Phrantela **n. sp. D**
Nicholls Range: Bill Nielson Cave (NR1)
n. genus? aff. *Phrantela*, n. sp.
Precipitous Bluff: Persephone (PB17)
"*Fluviopupa*" n. sp. A
Ida Bay: Mystery Creek Cave (IB10), Loons Cave (IB2), Comet Pot (IB98)
"*Fluviopupa*" n. sp. c.f. A
Junee-Florentine: Cauldron Pot (JF2), Rift Cave (JF34), Junee Cave (JF8)
"*Fluviopupa*" n. sp. B
Precipitous Bluff: Persephone (PB17)
"*Fluviopupa*" n. sp. C
Junee-Florentine: 'Wherrets Cave' (JF-x6)
"*Fluviopupa*" n. sp. F
Lower Maxwell River: 'Cricket Cave' (LM-x1)
"*Fluviopupa*" n. sp. G
Mount Ronald Cross: Capricorn cave (MR204)
"*Fluviopupa*" n. sp.
Bubs Hill: unidentified cave
Fluvidona **n. sp. A**
Ida Bay: Mystery Creek Cave (IB10), Loons Cave (IB2)
Fluvidona **n. sp. c.f. A**
Ida Bay: Comet Pot (IB98)

***Fluvidona* n. sp. B**
Precipitous Bluff: Persephone (PB17)
***Fluvidona* n. sp. C**
Loongana: Mostyn Hardy Cave (L4)
***Fluvidona* n. sp. D**
Gunns Plains: Weerona Cave (GP2)
***Fluvidona* ? n. sp. D**
Junee-Florentine: Junee Cave (JF8)
***Fluvidona* n. sp.**
Ida Bay: Little Grunt (IB23), Exit Cave - Eastern Passage & Kellars Squeeze (IB14)
***Fluvidona* sp.**
Ida Bay: Skyhook Pot (IB34)
***Beddomeia* n. sp. A**
Precipitous Bluff: Cueva Blanca (PB4), Persephone (PB17)
***Beddomeia* n. sp. B**
Loongana: Mostyn Hardy Cave (L4)
***Beddomeia* n. sp. C**
West Maxwell-Algongkian: cave
***Beddomeia* n. sp. D**
West Maxwell-Algongkian: cave
***Beddomeia* n. sp. E**
Loongana: Swallownest Cave (L5)
***Beddomeia* n. sp. F**
Gunns Plains: Weerona Cave (GP2)
***Beddomeia* n. sp. G**
Gunns Plains: Weerona Cave (GP2)
Beddomeia* c.f. *hulli
Gunns Plains: Gunns Plains Tourist Cave (GP1)
***Beddomeia* group**
Cracroft: cave (C-x9) (=CRA90-9)
Pseudotricula eberhardi
Precipitous Bluff: Cueva Blanca (PB4), Damper Cave (PB1), Bauhaus (PB6) (Ponder 1992)
Unidentified Hydrobiidae
Risbys Basin: Ray Bender's Cave
Vanishing Falls: Salisbury River Cave, Waterfall Spring Cave

CHAPTER 3 DISTRIBUTION AND EVOLUTION OF TROGLOBITES

A feature of cave faunas generally is the high degree of endemism, and Tasmania has many examples of this. For terrestrial cave organisms in temperate zone caves, the general consensus (Barr 1968, Peck 1981) is that their immediate ancestors were forest soil- and litter-dwelling animals that invaded caves and were isolated there during Pleistocene interglacials (Culver 1982). Inimical climate changes during the late Cainozoic Era are seen as important in causing surface extinctions (Barr & Holsinger 1985). Many terrestrial troglobite species are derived from hygrophilic forest-litter and soil dwelling ancestors. These species are pre-adapted to life in the cool, wet environment of caves. Therefore, caves may act as refugia for populations when surface conditions are unfavourable. Subsequent genetic divergence of these isolated populations, along with specialization to an obligate subterranean existence, explains the highly disjunct distribution patterns. A different explanation has been proposed for the evolution of terrestrial troglobites in tropical cave regions, called the adaptive-shift theory. This theory has helped to explain the discovery of terrestrial troglobites living sympatrically or parapatrically with their close surface relatives, and it may prove to be relevant in temperate caves as well (Howarth 1987).

More so than for mainland Australia, the Tasmanian cave fauna shows a pattern of similarity with the cave faunas of other glacial and periglacial regions such as New Zealand, Japan, United States and Europe. The geomorphological evidence indicates that profound environmental changes occurred during the late Cainozoic Era in many Tasmanian karsts and that some of these changes were partly facilitated by vegetation changes on the surface that were driven by climatic change (Kiernan & Eberhard in press). Hence, it is to be anticipated that evidence of these changes might also be demonstrable in the cave fauna.

Disjunct distribution patterns seen in the genus *Hickmanoxyomma* may be the result of vicariance, from the extinction of a widespread surface-dwelling ancestor. This endemic genus of cave harvestmen has recently been reviewed by Hunt (1990). Seven species are presently known throughout Tasmania. *Hickmanoxyomma cavaticum* is recorded from the Ida Bay, Hastings and North Lune karst areas. *H. goedei* occurs at Scotts Peak and Nicholls Range, whilst *H. clarkei* occurs at Cracroft and Precipitous Bluff. *H. eberhardi* and *H. cristatum* are found only at Mount Anne and Precipitous Bluff respectively.

At Precipitous Bluff, the distributions of *H. cristatum* and *H. clarkei* overlap, which may suggest at least two separate phases of cave invasion by a single progenitor species. This is consistent with geomorphic evidence for multiple episodes of cold glacial climate (Kiernan & Eberhard in press). There is some suggestion of habitat partitioning between these two species; the more highly cave adapted *H. cristatum* is found in the deep cave zone whilst the lesser cave adapted *H. clarkei* occurs closer to entrances. The dispersal ability of *Hickmanoxyomma* spp. appears to be very limited. Preliminary allozyme studies suggest that the Hastings and North Lune populations of *H. cavaticum* might well be genetically isolated despite being only 3 km apart, with no intervening barrier except lack of caves (Hunt 1990).

In the mountainous regions of southern and western Tasmania, where periglacial conditions were more extreme, *Hickmanoxyomma* spp. are exclusively cavernicolous. The Mount Anne karst was at least partly over-ridden by glaciers, and other karst areas such as Cracroft and Precipitous Bluff lay marginal to ice (Kiernan 1982a). However, in the north-east and north coastal lowlands, where periglacial conditions were more moderate, the surface dwelling *H. tasmanicum* is found. The high degree of troglomorphy shown by both *H. eberhardi* (ex Mount Anne) and *H. cristatum* (ex Precipitous Bluff) indicates they may have been isolated in caves for a longer period of time than their congeneric relatives. Conversely, *H. goedei* from the unglaciated low altitude karsts at Scotts Peak and Nicholls Range is less troglomorphic.

Distribution patterns seen in the harvestmen are paralleled in other groups of terrestrial troglobites such as cave beetles in the Family Carabidae, a group with hygrophilic and geophilic habits, which are largely confined to the temperate regions of both hemispheres. Two carabid tribes are represented in Tasmanian caves, the Zolini and Trechini. The zolines are confined to Australasia, while trechines are dominant elements in cave faunas of North America, Europe, Japan and New Zealand.

Within the Zolini, the relict genus *Idacarabus* is exclusively troglobitic. Species within this genus are found only in the alpine and montane impounded fluviokarsts of southern Tasmania. *Idacarabus troglodytes* is restricted to the Ida Bay karst, whilst *I. cordicollis* and *I. longicollis* occur at Hastings and Precipitous Bluff respectively. The fact that these 3 species form a graded series, in terms of decreasing cave-adaptation, over a small arc from south-west to north-east, may reflect the length of time the separate populations have been confined to caves in the three localities (Moore 1978). This distribution parallels the palaeoclimatic gradient suggested by a northeastward rise in cirque floor altitudes across southwest Tasmania (Kiernan & Eberhard in press). Glaciers are likely to have formed earliest and persisted longest in the southernmost cirques. Glaciers may also have formed there during cold climate phases that were too marginal for significant ice accumulation in more inland and more northern areas.

Pterocyrtus sp. is the other zoline beetle found in caves. An undescribed species inhabits the low relief riverine karsts of the Gordon and Franklin Rivers. Unlike *Idacarabus*, however, epigean congeners are known.

Similar disjunct distribution patterns are seen in the trechine cave beetles. *Goedetrechus mendumae* and *G. parallelus* are troglobites from Ida Bay and the Florentine Valley respectively. The latter species has vestigial eyes and the former has lost all trace of eyes. Interestingly, a third congener with vestigial eyes, *G. talpinus*, is endogeous and known from north-east Tasmania (Moore 1972a).

The harvestmen and beetles are two lineages of troglobites in which isolation and extinction of the surface fauna during late Cainozoic climate changes have been invoked to explain their evolutionary development. Environmental change as a mechanism for speciation is not necessarily confined solely to troglobites. Richards (1971a) suggested that the effects of Pleistocene glaciation were important in explaining the distribution and derivation of species-complexes in the troglophilic cave crickets in the genus *Micropathus*. In the northern hemisphere, climatic changes at the time of glacial retreat are presumed to have led to the extinction of surface fauna (Barr & Holsinger 1985). In Tasmania the advent of glacial climates, which were cold, windy and dry, may have been important in causing surface extinctions Hunt (1990). Unfortunately there is a paucity of information concerning other groups of cave animals, on which to test these ideas.

Different explanations are likely to be involved in explaining the evolution of the aquatic fauna. Tasmanian caves support a rich and highly diverse assemblage of hypogean crustaceans, in particular the syncarids (Anaspididae, Koonungidae & Psammaspididae), but also amphipods, phreatoicids and heteriids. There is also a rich fauna of hypogean molluscs belonging to the family Hydrobiidae. The lack of phylogenetic hypotheses about the relationships between species in these groups limits the speculations which can be made.

Some preliminary observations can be made however. The absence of the crangonyctoid amphipod genus *Neoniphargus* from cave collections is interesting in view of its abundance in hypogean habitats outside caves. *Neoniphargus* spp., usually blind and depigmented, are commonly collected in the pholeteros of crayfish burrows (Lake & Coleman 1977; Horwitz 1988). Their absence from caves suggests that at least the amphipod component of the Tasmanian cave fauna did not develop from hypogean ancestors, but from surface waters, where the other cave amphipod genera have many representatives.

On a regional level, Tasmanian karst areas appear to contain a number of distinctive cave faunal assemblages and community types. The geomorphic type of karst, past climate change, biogeographical and other factors appear to influence the composition of these assemblages. For example, Precipitous Bluff has experienced major environmental change and exhibits one of the richest assemblage of cave obligate species, as well as the most highly troglomorphic forms presently known in Tasmania. The fauna of the western riverine karsts, where environmental change is believed to have been more limited, appears less diverse and generally less troglomorphic. The biodiversity of karst systems, and the factors influencing it, are discussed in the next chapter.

CHAPTER 4. BIODIVERSITY OF KARST SYSTEMS

4.1 Introduction

How do the recorded levels of species diversity compare between different karst systems within Tasmania, and also mainland Australia, and what factors influence it ? This chapter compares the fauna of three karst systems in southern Tasmania, namely Exit Cave, Precipitous Bluff and Vanishing Falls. A karst system may be defined as all the caves developed within the same hydrological catchment, or contiguous catchments. These karst systems were amongst the most intensively sampled in Tasmania. An attempt is made to explain similarities and differences between the systems. The factors influencing biodiversity in karst systems and caves are discussed. Cluster analysis was used to classify caves into different types based on their faunal communities. Appendices 5 and 6 list the species recorded from each of the systems.

4.2 Exit Cave karst system

4.2.1 Introduction

The Ida Bay Caves have a long history of biological investigation. An article published in *Scientific American* refers to the spectacular glow-worm display in Mystery Creek Cave (Anon. 1895). This cave is the type locality for the species, *Arachnocampa {Arachnocampa} tasmaniensis* Ferguson, which is endemic to Tasmania (Harrison 1966).

Beetles were the first species described from the Ida Bay Caves. Lea (1910) described three species from Mystery Creek Cave, *Cyphon doctus* (Dascillidae), and two carabids, *Idacarabus troglodytes* and *Tasmanorites flavipes*. *I. troglodytes* was the first troglobitic beetle described from Australia. Moore (1972a) subsequently described another new genus and species of beetle, *Goedetrechus mendumae* known only from Exit Cave. Lacking eyes, this species was at the time, the most strikingly adapted troglobitic carabid yet discovered in Australia.

Mystery Creek Cave is also the type locality for the troglobitic harvestman, *Hickmanoxyomma cavaticum* (Hickman 1958). This endemic genus has recently been reviewed by Hunt (1990).

Biological discoveries have been made sporadically through the years. For example, Goede (1967; 1977a) documented the first occurrence of cave obligate millipedes in Tasmania, and the first record of aquatic Crustacea, from the Ida Bay Caves: gammarid amphipods and *Anaspides* (Syncarida: Anaspidacea). The only bathynellid (*Atopobathynella* sp.) so far recorded from a Tasmanian cave comes from Exit Cave (Goede 1975). Other early references to Ida Bay cave fauna can be found in Mann (1974), Richards (1964a), Skinner (1973) and others.

Much of this early work consists of scattered records showing the existence of a diverse cave fauna, which in some cases has been followed up with taxonomic description of the species. Thus, in reporting on the ecological protection of Exit Cave, Richards and Ollier (1976) collated existing information and produced a species list for the area. They found that the Ida Bay Caves have a troglobitic fauna distinct from that in neighbouring Hastings Caves.

Exit Cave is located within the Ida Bay karst area. The Exit Cave system is the longest in Tasmania. It comprises more than 17 km of passages in Exit Cave, plus other caves in the same hydrological system including Mystery Creek Cave and Little Grunt Cave. The list in Appendix 5 comprises all the different types of animals which have been recorded from the Exit Cave karst system at Ida Bay. There are other underground drainage systems in the Ida Bay karst, namely those associated with the Bradley Chestermans Cave, Loons Cave and Arthurs Folly Cave systems respectively, but their fauna is not included in the analysis which follows.

4.2.2 The fauna

There are minimally 73 different taxa which have been recorded from caves within the Exit Cave karst drainage system. The fauna includes one species each of nemertine and nematomorph; two species each of platyhelminth and annelid; three species of myriapod; six mollusc species; 13 crustacean species, 20 arachnid species and 25 insect species. Fifteen of these taxa are troglobitic or stygobiontic, and one more is possibly troglobitic. At least 20 taxa are accidental cavernicoles. As further research is done the list will be extended, but this level of biodiversity ranks amongst the richest for any karst area in the temperate zone of Australia.

4.3 Precipitous Bluff karst system

4.3.1 Introduction

The Precipitous Bluff karst area is located on the lower western slopes of Precipitous Bluff, 8 km north of Prion Beach on the central south coast of Tasmania. Precipitous Bluff itself rises abruptly from the shores of New River Lagoon to an elevation of 1145m. The local geology is described by Burrett*et al.* (1981), and by Dixon & Sharples (1986). The exposed basal rocks are Ordovician quartzites, overlain by Gordon Subgroup carbonates (Ordovician) which reach an elevation of about 400m a.s.l. These are overlain by Permo- Carboniferous sediments and the summit of the Bluff is capped by dolerite. There is extensive karst development in the Gordon limestone units.

The area experiences a cool temperate climate. Bureau of Meteorology records taken at Maatsuyker Island, situated 32 Km south-west of Precipitous Bluff, give an average annual rainfall total of 1248 mm, annual mean maximum temperature of 13.9 ^{o}C and annual mean minimum of 8.5 ^{o}C. Prevailing winds are south-westerly and north-westerly.

The slopes of the mountain support a lush growth of vegetation which shows a succession of plant communities from lowland wet sclerophyll and rainforest, to alpine conifers. Some of the plant communities have remained unburnt, and essentially undisturbed, for at least 300 years, and much longer in the case of the conifer forests. Dolines serve as fire refugia for the rainforest species.

Cirques on the eastern side of Precipitous Bluff presumably fed a valley glacier occupying the upper Salisbury River during the late Cainozoic (Eberhard *et al.* 1992), and periglacial conditions likely existed over the karst area during cold climate phases.

The Precipitous Bluff karst is highly cavernous and more than 40 caves have been explored to date. The caves are large and actively developing systems with perennial streamways. The Bauhaus Cave system for example has 10 known entrances and more than 2.4 km of surveyed passage. The known vertical range for this system is 115 m but with horizontal passage development occurring on several different levels.

The first collections of invertebrate cave fauna were made on the 1973 Southern Caving Society expedition (Middleton *et al.* 1973; Kiernan 1975). These first collections showed that the caves held an interesting fauna of terrestrial troglobites. They included a new species of beetle, *Idacarabus longicollis* (Moore 1978); a new species of blind oniscid isopod; a new species of harvestman, *Hickmanoxyomma* sp., and millipedes assigned to the family Dalodesmidae. The widely distributed cave cricket, *Micropathus tasmaniensis* was also recorded. Other material which was collected consisted of epigean snails (*Caryodes dufresni* and *Tasmaphena sinclairi*), as well as Symphyla and unidentified spiders (Kiernan *et al.* 1973). Further collections by Goede (1978a) included specimens of *Idacarabus*, *Hickmanoxyomma* and spiders.

Until recently, this was the extent of documented knowledge. However, the Tasmanian Caverneering Club 1986 expedition showed there was still much fauna to be found in the caves (Eberhard *et al.* 1987). Subsequently an intensive sampling programme was undertaken on the 1988-89 expedition, with further sampling on the 1989-90 expedition, and in 1991. Precipitous Bluff is now one of the biologically better known karst areas in Tasmania.

4.3.2 The Fauna

The invertebrate cave fauna at Precipitous Bluff consists of 46 taxa, including one species each of platyhelminth and nematomorph; 2 species of annelid; 3 species of myriapod; 4 species of crustacean; 9 insect species, 12 mollusc species (6 of which are accidentals) and 14 arachnid species. Of these, 15 species are troglobites or stygobionts, while another 4 species may possibly be so. Seven taxa are accidental cavernicoles.

Apart from the high number of troglobitic species, there are several other interesting aspects to the cave fauna at Precipitous Bluff. Firstly, several of the species are highly troglomorphic. Secondly, it is the only Tasmanian karst area which contains more than three troglomorphic species of harvestmen, four species having been recorded to date (Hunt pers. comm.). Two of these species, *Hickmanoxyomma cristatum* and *H. clarkei* were recently described by Hunt (1990), this being the first recorded sympatry within this genus. The more highly troglomorphic *H. cristatum* is found in the deep cave zone whilst the less troglomorphic *H. clarkei* occurs closer to entrances. *H. clarkei* also inhabits the Cracroft caves. *H. cristatum* is the most troglomorphic species in the genus (Hunt 1990), but is more closely related to two congeneric species inhabiting caves at Mole Creek and Flowery Gully.

A third species of harvestman from Precipitous Bluff belongs in the genus *Lomanella* (Hunt & Hickman in press). This particular species is completely blind. The fourth cave adapted harvestman at Precipitous Bluff is a new species in the genus *Mestonia* (Hunt pers. comm.).

Another cave obligate animal which appears to be endemic to Precipitous Bluff is an aquatic snail, *Pseudotricula eberhardi,* a new monospecific genus within the Hydrobiidae (Ponder 1992). It occurs in large numbers, particularly in sections of clear, fast-flowing streamway in Bauhaus, Cueva Blanca and Damper Cave. The diversity of hydrobiid molluscs at Precipitous Bluff (6 species) is equal to the highest sympatric diversity seen anywhere in Australia (W. Ponder pers. comm.). Another common stygobiont which is a local endemic is the amphipod, *Antipodeus* sp. nov. (Family Paramelitidae). Like the harvestmen, it is the most highly troglomorphic member in this group of stygobionts.

Two other local endemics are carabid beetles. The zoline beetle, *Idacarabus longicollis,* is relatively common in several of the caves, but a new species of trechine beetle (related to *Goedetrechus mendumae* from Ida Bay) is known, to date, from only two specimens collected in Damper Cave. Another rare troglobite is the pseudoscorpion, *Pseudotyrannochthonius* sp. (Family Chthoniidae).

4.4 Vanishing Falls karst system

4.4.1 Introduction

Vanishing Falls is located about 9 km north of Precipitous Bluff, and about 18 km west of Ida Bay. The karst system at Vanishing Falls consists of a river passage more than 2 km in length, plus other smaller caves. One physical factor which strongly influences the ecology of the Salisbury River Cave is flooding, because this system has probably the greatest flow rate of any river cave in Australia. The main conduit is characterised by rapid and massive fluctuations in flow volume and velocity, and whole passage sections are subject to regular inundation and draining episodes. The vegetation in the Salisbury Valley is rainforest. Until recently, the fauna of the Salisbury Valley remained totally unknown, but two weeks of surveying has proven the existence of a rich fauna, although it is not as well studied as either Precipitous Bluff or Ida Bay.

4.4.2 The fauna

The cavernicolous fauna consists of at least 30 taxa, comprised of 1 platyhelminth, 1 oligochaete and 1 symphylid; 2 molluscs and 2 diplopods; 7 insects and 7 crustaceans, plus 9 arachnids. Fourteen of these taxa are classified as troglobites or stygobionts, while 3 others may possibly be so. Like other karst areas in southern Tasmania, the invertebrate cave communities at Salisbury River are relatively diverse, and there is a rich assemblage of cave obligate species.

All the groups recorded are characteristic inhabitants of the different cave habitats sampled. Collectively, they represent a typical invertebrate cave community found in Tasmania. However, this brief survey could not cover all the possible types of habitat available to cave invertebrates and there are several notable absences from the list. These absences include the syncarid *Eucrenonaspides,* which is unusual because it is known to occur at nearby karst areas including Precipitous Bluff, Cracroft and Ida Bay. These animals are rare and cryptic however, as are the trechine cave beetles. Trechines were not recorded either, but they do occur at Ida Bay and Precipitous Bluff. The harvestmen fauna in the Salisbury comprises at least two species, including the widespread cave genus *Hickmanoxyomma.* A genus which was not recorded is *Lomanella,* but it occurs at other nearby karst areas. Amongst the spiders, representatives of *Olgania* and *Tupua* were not recorded. A conspicuous new genus and species of hydrobiid snail, *Pseudotricula eberhardi,* was not seen either, so this unusual snail appears to be confined to the Precipitous Bluff caves (Ponder 1992). Further searching may well reveal the presence of some, or all, of these groups in the Salisbury.

Like the Precipitous Bluff fauna, the Salisbury fauna is of particular interest due to the comparatively high degree of troglomorphy exhibited by some of the taxa. The implication is that these taxa have been isolated in caves for a longer period of time than their less troglomorphic congeners from other areas. The cave beetle, for instance, is a new species in the genus *Idacarabus*. It shows a high degree of troglomorphy, comparable with, or possibly more troglomorphic, than *I. longicollis* from Precipitous Bluff. Similarly, the amphipod *Antipodeus* 'stygobiont 1' is highly troglomorphic because it lacks all pigment and eyes, and possesses relatively elongate appendages. Entomobryid springtails collected from the Salisbury appear highly troglomorphic also, they possess very long appendages, the antennae and claws in particular. Other features to be revealed about the fauna await more detailed studies.

Aquatic habitats were found to be rich in both species and individuals. One small seepage fed watercourse in the Salisbury River Cave, for example, contained a total of 6 taxa including planarians, syncarids, amphipods, heteriids and at least two species of hydrobiid. The hydrobiid mollusc fauna is widespread and abundant in the Salisbury caves, but it appears to lack the level of diversity (6 species) which is found at Precipitous Bluff. A species of small, white planarian is common in seepage habitats, and it may be a stygobiont. At least two forms of *Anaspides* were found underground, an epigean form with normal pigmentation, plus a non pigmented form. One vertebrate was recorded underground, a galaxiid fish was sighted in the Salisbury River Cave.

The flooding episodes in Salisbury River Cave affect the distribution and behaviour of organisms. Floods carry in food sources in the form of detritus, leaves, wood and accidentals but floods also could potentially displace both terrestrial and aquatic animals alike. The optimum habitats for several of the terrestrial troglobite species appeared to be immediately above the normal regular flooding level, but still within the zone of occasional flooding. Likewise, some of the seep dwelling species such as *Antipodeus* are evidently able to cope with periodic inundation by the main stream waters.

4.5 Discussion

The karst areas of southern Tasmania rank among the richest, biologically, in the temperate zone of Australia. They support 15 or more cave obligate species, including some of the most highly troglomorphic representatives in several genera, such as amphipods (genus *Antipodeus*), beetles (genus *Idacarabus*), harvestmen (genera *Hickmanoxyomma, Lomanella* and *Mestonia*) and molluscs (*Gen. et sp. nov.*). The Cracroft is a major karst area in the southern region which has not been subject to intensive biological survey, but collections already made hint at the existence of a rich fauna.

In northern Tasmania there are major karst areas with rich faunas, but only Kubla Khan Cave has been subject to intensive survey, revealing 71 taxa with 11, or possibly 13, cave obligate species (details in Chapter 5). In western Tasmania, the Bubs Hill karst has been intensively surveyed, with at least six definite troglobites and six other taxa of uncertain status recorded (Clarke 1989a). One cave at Bubs Hill contained over 55 taxa, although nearly half of these were accidental cavernicoles (Houshold and Clarke 1988). The *Hickmanoxyomma* and trechine beetle species from northern and western karst areas appear generally less troglomorphic than their southern counterparts.

How does biodiversity compare between the karst systems which have been subject to intensive surveys ? Table 1 compares the taxonomic and ecological diversity of four major karst systems, *viz.* Exit Cave, Precipitous Bluff, Vanishing Falls and Kubla Khan.

The total number of taxa recorded varies from 30 to 73. This wide range is partly an artefact of the different sampling programmes. Precipitous Bluff and Vanishing Falls had the lowest totals (46 and 30) because the collecting was biased towards troglobitic and troglophilic species, whereas accidental species were largely ignored. Also, Vanishing Falls has not been as intensively sampled as the other sites. The number of troglobitic taxa is similar between all areas however.

How does this diversity compare with the rest of Australia ? Few published data are available, but it appears that Tasmania is the stronghold of the richest cave faunal assemblages in Australia's temperate zones. Richards (1971c) records six troglobites from the Nullarbor Plain, but several more have since been collected (e.g. Knott 1983). In Victoria, at least five troglobites are known from three cave areas (S. White pers. comm.). From Wombeyan Caves in New South Wales, Smith (1982) records two troglobites and five "second level" troglophiles (*sensu* Hamilton-Smith 1967). At Bungonia Caves, also in New South Wales, two species of second level troglophile are reported (Wellings 1977). Jasinska and Knott (1991) recorded 25 species of aquatic cavernicoles from a cave at Yanchep in Western Australia.

In Australia's tropical regions, much higher levels of diversity can be expected. Humphreys (1989) documented at least 15 cave obligate species from the Cape Range in Western Australia. From a single lava tube in northern Queensland 24 species obligatorily adapted to subterranean life have been found (Howarth 1988). This particular site (Bayliss Cave) is exceptionally rich, ranking amongst the richest in the world (Malipatil & Howarth 1990).

Comparisons of biodiversity such as this are rather crude, because there will be differences in sampling intensity between different areas and the fauna of many karst areas is still incompletely known. The comparison is also complicated by biogeographical and historical factors, and the area effect; *i.e.* in a geographical region where climatic conditions are historically similar, areas with extensive, continuous exposures of cavernous limestone will harbour more diverse troglobite faunas than areas with limited, discontinuous exposures of limestone (Holsinger & Culver 1988). In comparing the regional cave faunas of different drainage basins in Virginia and a part of Eastern Tennessee, Holsinger and Culver found a strong linear relationship between cave species diversity and cave density.

Although no hard tests have been carried out, factors which may be related to species diversity in Tasmania, at the karst systems level, include the size of the karst area, cave size and density, age of the caves, vertical relief of the limestone outcrop, and condition of the surface vegetation. At the level of individual caves, biodiversity may be related to cave size, cave geomorphic type and cave habitat characteristics. Diversity at the systems level is discussed below, whilst diversity at the cave level is investigated in section 4.6 following.

(1) Size of the karst area. Larger, cavernous karst areas have more species.
(2) Density of caves. Densely cavernous areas have more species.
(3) Size of the karst system. Extensive karst systems have more species.
(4) Age of the karst system. Older karst systems are likely to have more species.

The points made in (1) to (3) above translate as an area effect (MacArthur & Wilson 1967). In general, larger caves will contain a greater variety of substrates. More kinds of substrate mean more habitat types and thus more potential kinds of organisms and more places to hide (Poulson and Kane 1977). These observations corroborate the hypothesis of Holsinger & Culver (1988), that geological structure directly affects cave species diversity and ecological complexity. Older karst systems may have been available for colonisation over a longer time period, and therefore they might have been colonised by more species than a younger karst system.

(5) Vertical Relief. The karst aquifer can be subdivided into three distinctive hydrological zones which correspond to major subsurface habitat types (Culver 1982). The lowest of these is permanently flooded (phreatic zone), above this is an intermittently flooded zone (active vadose zone) and an upper, dry zone (inactive vadose zone). Each zone may have its own distinctive fauna. Thus, karst areas with sections of cave passage developed above the phreatic zone generally have more species. Vertical relief allows passage development on several levels, so the fauna can migrate up and down the karst aquifer and thus potentially withstand episodes of conduit infilling and rises in base level such as occur during glacial

Table 1. Distribution of major taxonomic groups, and ecological status, between different karst systems (numbers of species recorded).

	Precipitous Bluff	Exit Cave	Vanishing Falls	Kubla Khan
Platyhelminthes	1	2	1	3
Nematomorpha	1	1	0	0
Nemertea	0	1	0	0
Annelida	2	2	1	5
Myriapoda	3	3	3	5
Crustacea	4	13	7	6
Arachnida	14	20	9	21
Insecta	9	25	7	23
Mollusca	12	6	2	5
Number of troglobites	15	15	14	11
Possible troglobites	4	1	3	2
Number of accidentals	7	20	1	19
Total number of taxa	46	73	30	71

periods. Conversely, the fauna can migrate downward when base levels are being lowered. Deep cave systems probably provide more stable "deep cave zone" refugia for species, because they are insulated by more rock. Shallow cave systems more easily dry out, and offer less buffering capacity against environmental changes occurring on the surface.

(6) Condition of the surface vegetation. Surface vegetation is important for promoting cave development in the first place, by increasing soil microbial carbon dioxide levels and hence aggressive waters to dissolve the rock. Tasmania's native wet forests have a rich invertebrate fauna, and several forest species also colonise caves. The closest surface relatives of many cave-limited species are in the litter of temperate forests (Culver 1982). Native forests provide nutrients to drive cave ecosystems, for example, tree roots, gravity input of logs and litter at entrances, stream flow and accidental cavernicoles. Caves which have had the native vegetation removed from their catchments and around their entrances have a depauperate fauna. Cave crickets provide an obvious link in this respect since they emerge from caves to feed, and are dependent on a lush surface vegetation of wet forest plants, especially mosses and liverworts. An old and structurally complex native forest will have greater invertebrate diversity than a young eucalypt monoculture, exotic pine plantation, or land cleared to pasture. A forest cover insulates caves from extremes of temperature, and low humidity, which cavernicoles are particularly sensitive to. Based on the only surface collection of a troglobitic harvestman species, Hunt (1990) proposed that mesocavities in or under logs of Tasmanian forests virtually reproduce the cave environment on the surface. This microclimate concept can be extended to include the entire ground and litter layer of a closed canopy wet forest, under the right conditions, and has important implications for the dispersal opportunities of so-called cave obligate cave species. Also for troglophilic species, such as *Hickmania troglodytes* and *Micropathus* spp., removal of the native vegetation increases the isolation of previously panmictic populations.

The age and richness of the Precipitous Bluff fauna, for example, may be related to the apparent long term stability of the vegetation in this region, which has remained unburnt and undisturbed since the arrival of European man, and possibly since the Pleistocene. The vegetation consists of ancient rainforest and sub-alpine coniferous forests. Other karst areas are cloaked in mature rainforest, but Precipitous Bluff is uniquely situated with respect to its coastal proximity, and the ameliorating effect this has on local climate. Karst areas situated more inland, likely experienced a greater range of extremes during fluctuations in climate, with forests retreating below the karst at times. Long term stability of the surface vegetation, it could be argued, would ensure the survival of more species, whilst areas subject to less stability would experience more extinctions. Regions lacking forests throughout the Pleistocene, such as parts of the American Southwest and Australia (Peck 1980), have a very depauperate terrestrial cave fauna (Culver 1982).

4.6 Biodiversity of caves

4.6.1 Summary

Cluster analysis was used to classify 41 caves at Ida Bay into different types, based on their faunal communities. The faunal communities found in these different cave types are correlated with cave size (or area effect), cave geomorphic type and cave habitat characteristics. There appears to be a general relationship between species richness and cave size.

4.6.2 Introduction

How does biodiversity vary between different caves within the same karst system, and what factors influence it ? The karst aquifer can be divided into vertical zones which correspond to major subsurface habitat types. The lowest of these is the phreatic zone, which is below the water table and permanently water filled. Above this is a periodically flooded zone (active vadose zone) and an upper, dry zone (inactive vadose). If the subterranean fauna is very rich, the different karstic zones tend to have different faunas (Culver 1982).

This section describes an intensive study which compares the fauna between 61 caves within the Ida Bay karst system. The caves are classified according to their faunal characteristics. An attempt is made to relate the classification to the scheme of Culver (1982) described above, as well as to other environmental parameters.

The study area is densely cavernous, with more than 70 caves occupying an area of less than 2 km^2. It encompasses Bradley Chestermans Cave and a region known as The Potholes, which drain into Exit Cave. The two drainage systems are contiguous, and are possibly connected by underground passages. Bradley Chestermans Cave is a perennial outflow cave 286m long. It is located in the active vadose zone, whereas The Potholes are in the inactive vadose zone. The entrances to the potholes are usually abrupt shafts, or where entrances are horizontal these frequently intersect descending shafts after a short distance. The potholes are generally dry, with little or no flowing water, although seepage waters continually feed into the them and standing water persists at the base of deeper shafts. Under wet conditions, The Potholes are sinks for ephemeral watercourses, and some of them are very deep, being multiple shaft systems descending 130m below the surface.

4.6.3 Methods

Each cave was visited once and the fauna recorded by thoroughly searching all accessible area of floor, walls and roof. Particular attention was given to recognised micro-habitats including logs and litter, mudbanks, tree roots, pools, watercourses and underneath stones. Surveying commenced in daylight at the cave entrance, and then progressed inwards through the twilight zone, transition zone, dark zone and deep cave zone respectively. The length of passage in each cave was calculated roughly by pacing measurments. Cave descriptions are given in Eberhard (1990c).

The data were subjected to a cluster analysis following standard procedure (e.g. Richardson and Swain 1989). Similarities between sites were measured using Jaccard's coefficient on species presence/absence data. The resulting dissimilarity matrix was clustered using the group average (UPGMA) method, and shown as a dendrogram. The cluster analysis was carried out on a reduced data set containing 21 species and 41 sites. Species recorded from fewer than 3 sites, or sites with fewer than 3 taxa, were excluded. Analyses were performed by the program BIOΣTAT II.

4.6.4 Results and Discussion

The size of caves ranged from 1.5 metres to 286 metres in length. They were divided into four size classes according to passage length, or depth of penetration beneath the surface. The majority of caves (68%) were less than 20 metres in extent and were classified as Twilight Caves because they did not extend into the dark zone. Small Caves (20-50m) represented 17% of the sample, Medium Caves (50-100m) 8% and Large Caves (>100m) 7%.

Of the taxa recognised, 50% were identified to generic or species level. A total of 316 species-site records were obtained for 59 caves, representing 84% of the caves known to occur in the study area.The fauna (excluding accidentals) consisted of a minimum of 30 species, belonging to 12 orders and 23 families. This included one species each of flatworm, oligochaete, myriapod and mollusc; two species of springtail, four species of crustacean, seven species of insect and thirteen species of arachnid. At least nine of these species were terrestrial troglobites and two were stygobionts. All of these cave obligate species were arthropods, representing 36% of the cavernicolous fauna. A list of the fauna and locality records is given in Appendix 6.

The dendrogram (Fig.19) showed a basic division of the sites into two major groups, Bradley Chestermans Cave and The Potholes. This division was based partly on species richness and composition of the faunal assemblage, cave size and geomorphic-habitat characteristics. Bradley Chestermans Cave had the highest recorded species diversity (16 species), which is not unexpected since it was the longest cave surveyed, and ecological theory predicts a general relationship between habitat area and species richness (MacArthur & Wilson 1967). In this instance, cave length (or size) appears to equate with habitat diversity and the area effect. The number of terrestrial species in this cave remained high, despite extinction of some of the aquatic fauna by pollution from a limestone quarry (see next chapter).

In addition to species richness, the composition of the cave communities also contributed to the initial division. Bradley Chestermans Cave showed an absolute difference in the presence of three taxa: *Styloniscus* sp. nov. A, Troglopetini Gen. *et* sp. nov. and Symphyla.

The primary division between The Potholes and Bradley Chestermans Cave was further evident in the context of geomorphic-habitat type. As outlined earlier, the karst aquifer can be divided into vertical zones which correspond to major subsurface habitat types (Culver 1982). Bradley Chestermans Cave was situated in the active vadose zone whilst The Potholes were in the inactive vadose zone. The other major subsurface habitat type is the phreatic zone, which was not sampled. The extent of the different zones depends on the vertical relief of the limestone outcrop.

The Potholes were subdivided into two major groups, consisting of twilight caves against a somewhat heterogeneous grouping including some twilight caves and all other larger caves. Nevertheless, these groupings were consistent in their relationship to species richness and area effect. Within the grouping of "larger" caves, there was a clear dichotomy between those with an aquatic fauna and those without. Those caves with an aquatic fauna were all deep or large sized caves. This is because it is only at some depth below the surface that seepage waters coalesce sufficiently to develop a semi-permanent aquatic habitat.

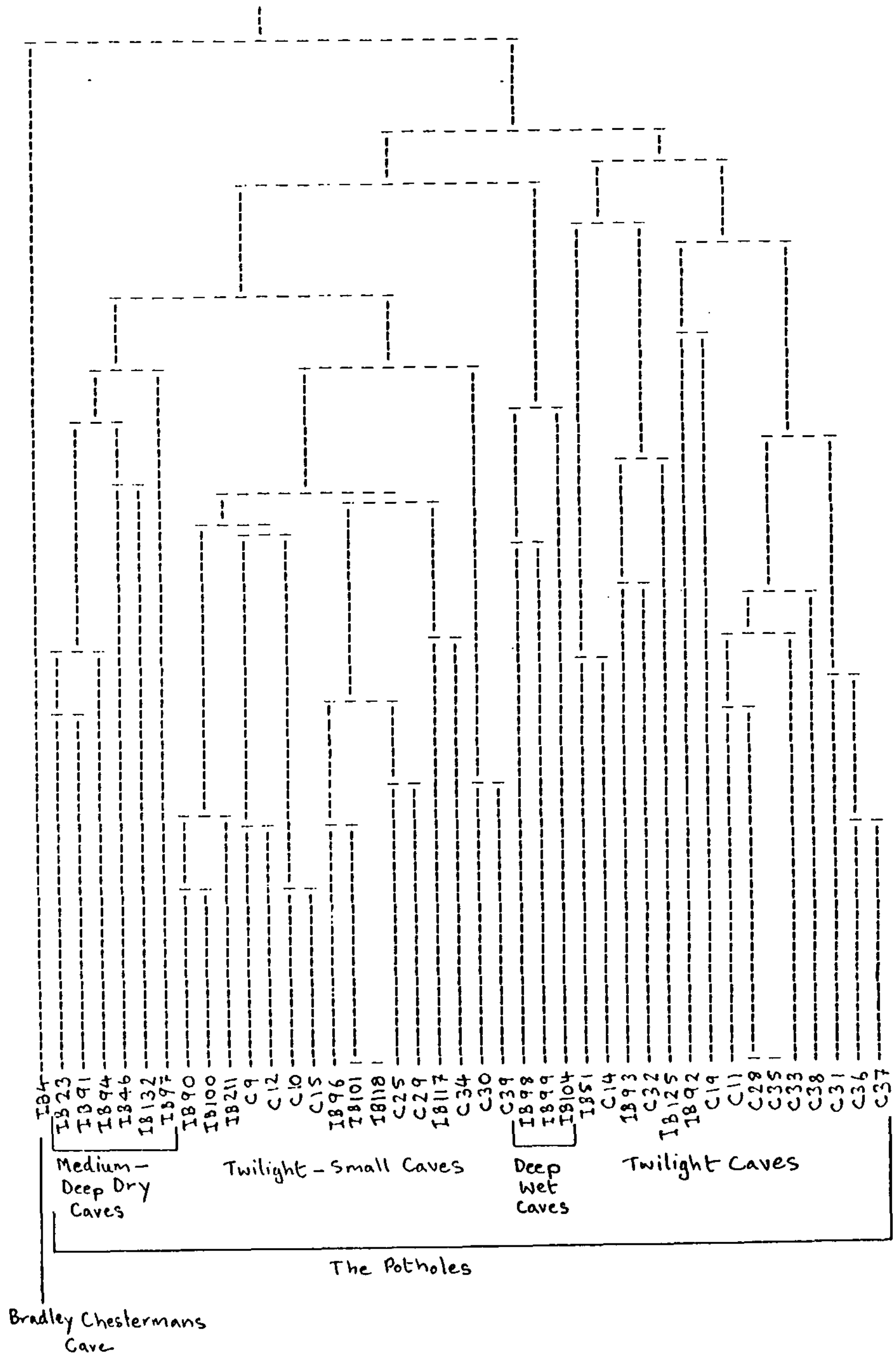


Figure 19. Dendrogram resulting from cluster analysis of 41 cave sites by 21 species.

In summary, the caves in the study area were classified into a number of distinct hierarchical groups based on their faunal assemblages. These were:
(1) Active vadose zone caves (=Bradley Chestermans Cave).
(2) Inactive vadose zone caves (=The Potholes).
--------------(2.1) Twilight caves
--------------(2.2) "Larger" caves, ranging in size from small (<50 m long) to medium (50-100 m) to large (>100 m).
----------------------------(2.2.1) Wet caves
----------------------------(2.2.2) Dry caves

The faunal assemblages found in these different cave types appeared to be related to three ecological parameters:
(1) Cave size, ie. area effect.
(2) Cave geomorphic type, or vertical zonation of the karst aquifer.
(3) Cave habitat characteristics, or presence/absence of distinct microhabitats such as streamways, seepages and pools, sediment banks and tree roots. There is potential for applying these cave classifications to conservation and management problems.

CHAPTER 5 CONSERVATION STUDIES

5.1 Introduction

Food webs in cave ecosystems are relatively simple in comparison with most other systems, and they are often regarded as fragile and vulnerable to disturbance. This poses special problems for conservation and management (Davey 1984), and for the study of cave ecology. Invertebrate cave communities in Tasmania are threatened by quarrying, soil erosion and pollution of underground water supplies, deforestation and the effects of logging and agricultural practises, as well as the impacts of visitors to caves. Baseline data on these impacts are lacking in many land management plans, but the situation is starting to improve. This chapter describes three case studies which use biological survey data to improve the conservation and management of karst in Tasmania. The first two studies investigate the deleterious impacts of quarry run off on cave fauna at Ida Bay. The last study addresses the conservation and management Kubla Khan Cave, with emphasis on minimisation of the impacts that caving activities have on the fauna.

5.2 The effect of quarry runoff on Bradley Chestermans Cave

5.2.1 Summary

Run off from a limestone quarry operation drains into Bradley Chestermans Cave at Ida Bay. The effects of the run off include sedimentation, gross pollution and local extinction of aquatic fauna. The fauna of this cave was compared with other caves nearby, which have not been affected by quarry run off.

5.2.2 Introduction

Bradley Chestermans Cave (IB4) is one of three major outflow caves which collectively drain the northern and western aspect of Lune Sugarloaf, and the northern aspect of the Lune Sugarloaf-Marble Hill divide. The other two caves are Loons Cave (IB2) and Arthurs Folly Cave (IB110). The entrances to these three caves are situated at about the same altitude, on the plain-slope juncture. They are located roughly along the line of an axis extending SW-NE, and just over a kilometre in length. The waters from the caves drain into Summers Creek.

These three caves are similar in that they are excavated in the same geological formation, and are extensive horizontal outflow systems. All three caves contain similar habitats for fauna, including tree roots, sediment banks and permanent streams. Arthurs Folly Cave and Loons Cave did not appear to be affected by run off from the quarry because their catchments lay outside the area of the workings, but Bradley Chestermans Cave was affected.

The outflow entrance of Bradley Chestermans Cave is located in the valley immediately north of Bender's quarry at Ida Bay. Survey data show that the cave passage extends some 200m linearly south, directly towards the quarry, and the catchment of the cave included the area of the quarry workings. Surface run off in the quarry drains into several holes (including IB127 *et al.*) which have been shown by dye tracing to connect with Bradley Chestermans Cave.

The impacts of the quarry operation on this cave have been evident for many years. There are reports of siltation and oil pollution in the cave (Clarke 1989b), also foul air and sickness caused to visitors:

'After a short time in the cave he felt ill and left chundering, not regaining full vim and vigour for some days. We didn't strike it that bad, but the smell did become nauseating after a time. It is somewhat oily, probably from diesel fuel, which starts to come through only after heavy rain.' (Kiernan 1973).

The aims of this study were to investigate the effects of the quarry operations on Bradley Chestermans Cave, and to compare the fauna with Arthurs Folly and Loons Cave.

5.2.3 Comparison of terrestrial fauna

The three caves contained similar terrestrial habitats including sediment banks and tree roots, and they shared a rare species of troglobitic isopod which is associated with the tree roots. Fifteen terrestrial species (including six troglobites) were recorded from Bradley Chestermans Cave and Arthurs Folly Cave (Clarke 1989b) respectively, whilst twelve species (including four troglobites) were recorded from Loons Cave (Eberhard *et al.* 1991). Quarry run off had not obviously depleted the number of terrestrial species in Bradley Chestermans Cave, but there may have been other subtle impacts associated with pollution of the stream. Potential impacts of quarrying on terrestrial cave fauna are discussed in Section 6.2.6 later.

5.2.4 Comparison of aquatic fauna

Bradley Chestermans Cave was visited in low flow conditions during this survey. There was no visible sign of oil pollution. However, there was evidence of recent sedimentation, local extinction of aquatic fauna and gross organic pollution. It seemed likely that these effects have been caused by the quarry operation.

The stream sediments in the cave consisted largely of pebbles and gravels, but in pools these were overlain by fine silt and clay sediment which was derived from the quarry. In addition to sedimentation, the substratum of the stream in Bradley Chestermans Cave was covered with growths of ragged, hair-like filaments. The filaments were less than 20mm long but the growth was dense and covered the entire substrate. Although it was not positively identified, this growth resembled 'sewage fungus', a term used to refer collectively to a variety of microorganisms (bacteria and fungi) that characteristically associate to form unsightly ragged masses (Bayly & Williams 1981). Sewage fungus is an indicator of gross organic pollution.

While Bradley Chestermans Cave had a normal community of terrestrial cavernicoles, the same was not true for the aquatic fauna. Table 6.1 compares the aquatic fauna of this cave with that found in the other two caves. Loons Cave and Arthurs Folly Cave harboured five and eight aquatic species respectively, which is typical for undisturbed stream caves in Tasmania (Eberhard *et al.* 1991), but Bradley Chestermans Cave had only one species definitely recorded.

Clearly, the aquatic community in Bradley Chestermans Cave was depleted in comparison to the other two caves. The only aquatic animals found in the cave were planarians, which were abundant in pools and riffles throughout the length of the streamway. However, the silty bottom of pools in the streamway were marked with sinuous tracks approximately 2mm in width, which were not made by planarians, but most closely resemble those made by syncarids, or possibly even a mollusc. Also present were frass piles up to 10mm in diameter. The syncarid *Anaspides tasmaniae* was recorded from this cave in the past (Matthews 1985). Despite thorough searching on this survey, no specimens of *A. tasmaniae* or any other macro-invertebrate (apart from planarians) were found.

5.2.5 Discussion

A decrease in species diversity is a general effect of organic pollution of inland waters (Bayly & Williams 1981). Concomitantly, there will often be an increase in abundance of one or a few species which are tolerant to the effects of pollution, and this would appear to be the case in Bradley Chestermans Cave. Holsinger (1966) investigated the effects of organic pollution in Banners Corner Cave in Virginia, and found an exceedingly large population (by hypogean standards) of planarians and isopods He suggested that cave planarians feed on faecal material and other organic detritus. The evidence given here supports the possibility that planarians may be a useful indicator species of organic pollution in caves.

In reporting on the conservation status of *Anaspides tasmaniae*, O'Brien (1990) classifies all cave forms as 'vulnerable', solely on the basis of their highly restricted distributions. In the case of *A. tasmaniae* in Bradley Chestermans Cave, this population is 'endangered', or possibly extinct.

5.2.6 Potential effects of quarry operations

Any quarrying activities pose a threat to the biophysical integrity of the karst system. Other potential impacts of quarry operations on cave fauna were identified below:

(1) Removal of Caves. Clearly this is devastating to the fauna directly in the path of the quarrying, but would the removal of some cave populations place at risk any of the Ida Bay cave species? There is no clear answer to this as the dearth of basic taxonomic and distributional data for many of the populations in question precludes an accurate assessment either way. Some species, or populations, do have extremely localised distributions, being restricted to only one cave, or a few closely situated caves. Examples of this include an eyeless form of *Anaspides*, known only from Wolfe Hole at Hastings (Lake & Coleman 1977), and *Styloniscus* sp. nov. A which appears to be restricted to Bradley Chestermans Cave, Arthurs Folly and Loons Cave.

(2) Edge Effects. These are taken to include the effects on caves not actually removed by quarrying, but situated on the immediate periphery of the quarry excavation and workings. Potential impacts include disturbance by shock waves from blasting; elevated temperatures and desiccation of the cave environment caused by localised solar heating in areas of exposed bedrock; alteration to airflow patterns in caves; sedimentation in caves receiving run off from the quarry operation; and removal or alteration to the vegetation surrounding cave entrances. The maintenance of a wet forest around entrances is important for the survival of cave crickets, and also the supply of litter fall and litter invertebrates which can be a major source of energy input into cave ecosystems. In addition, the dense forest cover insulates the entrance zones of caves from extremes of temperature and humidity. Thus, removal or deterioration of the forest cover will also facilitate local heating of the regolith and bedrock, and possible drying-out of cave atmospheres.

(3) Hydrological Impacts. Changes to water quality or flow regimes are potential impacts of quarry operations on karst hydrology. The effects of these impacts on the fauna are difficult to predict, and will vary with distance from the source of disturbance. Nevertheless, this study has strongly suggested that quarry run off has deleteriously affected the aquatic community in Bradley Chestermans Cave. Sediment-laden quarry run off has caused depopulation of hydrobiid snails in Little Grunt and Exit Cave (see section 6.3).

(4) Fragmentation of the Karst Biome. Fragmentation of populations through human-induced isolating mechanisms (such as the quarry excavation), pose a threat to the biophysical integrity of the Ida Bay karst. Cave species can disperse

through cracks and fissures in the bedrock, or through soil layers and forest litter on the surface. However, species which live in habitats such as caves where adversity selection (Greenslade 1985) is operating, characteristically have low vagility. Through removal of the surface vegetation, and bedrock, the area of quarry workings represents a substantial physical barrier to dispersal of cavernicolous species. The quarry excavations have dislocated the Marble Hill and Lune Sugarloaf sections of the Ida Bay karst. Thus, the opportunity for gene flow between populations found in each section of the karst may have been reduced, or even severed completely. Will the separate fragments of karst biome still be sufficiently large to maintain minimum viable populations? Populations in the area of Bradley Chestermans Cave, Loons Cave and Arthurs Folly appear to be at greatest risk from this potential impact.

5.3 The effect of quarry run off on population densities of hydrobiid molluscs in Little Grunt and Exit Cave

5.3.1 Summary

The ecological effects of quarry run off on the Exit Cave system are investigated. Run off from a limestone quarry operation is depositing fine clay sediment in cave streams. A comparison of population densities of hydrobiid molluscs is made between cave stream tributaries which are affected by quarry run off, and those which are not. There were significantly lower densities of hydrobiids in affected tributaries. The quarry operation has the potential for causing deleterious impacts to the aquatic fauna in caves at Ida Bay. The populations of aquatic species in the sediment affected tributaries of these caves are 'endangered'.

5.3.2 Introduction

Erosion by water results in suspended sediment carried by streams, which is eventually deposited on the stream bed. This deposited sediment can be of great significance to the aquatic fauna because of its modification of habitats (Berkman & Rabeni 1987; Doeg *et al.* 1987). Suspended sediment may also contribute to scouring of organisms from the stream bed during times of high flow (Tebo 1955; Chutter 1969). Benthic invertebrates are highly influenced by substrate type with a sharp distinction occurring between the fauna on hard and soft bottoms (Hynes 1970).

One family of benthic invertebrates occurring in streams is the Hydrobiidae. They are one of the most significant freshwater mollusc families in Tasmania because of their high species diversity (Ponder *et al.* 1988). Hydrobiids are small (<1 centimetre) gastropods and the majority of species live in small bodies of water (small streams, trickles, springs and seepages). They have low dispersal powers.

Many species have restricted ranges, sometimes being confined to single streams or, more commonly, to a single, minor drainage area (Ponder *et al.* 1988). The actual ecological limits of a taxon may be very restricted also, for example, in many taxa the area of a stream occupied may only be a few metres from the head of the stream. They are found on hard bottom substrates only, and not on soft bottom substrates.

Hydrobiids are abundant in the cave systems at Ida Bay, and elsewhere in Tasmania, where they live on rock surfaces in pools and riffles of small streams and seeps. The hydrobiids are readily seen, and counted, in these types of subterranean habitats. One stream passage in Little Grunt Cave, and the Eastern Passage of Exit Cave, has been affected by run off from a limestone quarry operation, but other stream passages in these caves have not. The affected stream evidently carries a relatively greater load of fine sediments. It extends beneath the area of quarry excavations and dye tracing has proved a hydrological connection between this tributary and sediment-laden water which sinks underground in the quarry. Hence, these two caves were selected to investigate the effect of quarry run off on aquatic cave fauna. The hypothesis is that hydrobiids may be sensitive to different degrees of sedimentation, and that the fine sediment being deposited in these tributaries is reducing the area of hard bottom substrate which is suitable habitat for hydrobiids. To hypothesise further, the habitat in these passages may be sub-optimal for hydrobiids because of the sedimentation, or because of other water quality changes associated with the quarry run off. The aim of this study then, is to make a statistical comparison of hydrobiid densities between the stream tributary which is affected by quarry run off, and those which are not.

5.3.3 Methods

Eight sample sites, consisting of 20 quadrats each, were used in stream passages in Little Grunt and Exit Cave. Sampling was stratified into two habitat types, pools and riffles. Sample sites were chosen to be similar to each other in terms of substrate type, water depth and flow rate. Snail densities were counted within a 20 cm x 20cm quadrat placed on the stream bed. All counts were made by carefully searching, and without disturbing, the whole area of the quadrat (this was facilitated by 1cm x 1cm divisions). The % cover of silt was estimated for each quadrat, and a reference collection of snails was taken from each site. In order to minimise bias in the selection of quadrat locations, a fibreglass tape was laid along the stream at each sample site. Quadrats were placed at 10 cm intervals along the transect line until 10 pool and 10 riffle samples were obtained. Other aquatic species present were noted. Sampling was undertaken during base flow conditions occurring over a four day period in February (14th to 17th) 1992. Results were analysed with Statview (Feldman & Gagnon 1986).

5.3.4 The study area

The Ida Bay karst system is located on Marble Hill in southern Tasmania (146° 50' E; 43° 28' S) The caves are developed in Ordovician limestones (Sharples 1979). Subsurface drainage in the area is characterised by very rapid infiltration of water into deep vertical cave shafts that are drained laterally from their base by major horizontal cave systems developed in the purest limestone strata (Kiernan 1991). Exit Cave forms a part of the major subsurface drainage network beneath Marble Hill. It consists of a branched network of passages and conduits (totalling 17 km in length) which collect water from a variety of sources. One of these is the Eastern Passage, which collects water off the south-eastern aspect of Marble Hill, as well as the area of the Marble Hill - Lune Sugarloaf divide. A limestone quarry operation situated on this divide intercepts the Eastern Passage catchment, as does Little Grunt Cave, but further upstream from Exit Cave (dye tracing has proven a direct hydrological link between the two caves, and also the quarry). The main conduit in Little Grunt is fed from two principal tributaries, referred to as the North Tributary and the South Tributary.

All streams in the system contain naturally occurring sediments ranging from sandy silt to large cobbles. The streams contain sediment of a bimodal composition, generally gravel to cobble sized clasts interspersed with finer material (Houshold 1992). An obvious difference between the North Tributary and South Tributary is that the finest material in the latter is sandy silt. This calibre of material is the finest found naturally throughout the Exit Cave system. In contrast, the North Tributary contains a great deal of fine clay and silty clay. The North Tributary extends underneath the area of quarry excavations, where surface run off from the quarry benches sinks underground and connects with it. The South Tributary, on the other hand, has its catchment in an area of natural forest vegetation.

The cave passage drainage system and location of sample sites are shown in Figure 6.1. Sample sites 2 and 8 are located in the North Tributary, while sites 1, 5, 6 and 7 are located in the South Tributary. Site 4 is in the Eastern Passage of Exit Cave, while site 3 (Base Camp Tributary) is a separate, but parallel, drainage conduit in Exit Cave.

5.3.5 Results

The hydrobiids were identified as a new species of *Fluvidona,* but it is unusual in that some of the specimens have very reduced or absent opercular pegs, and there is some variation in size and the development of the white material on the operculum (W. Ponder pers. comm.). Voucher specimens are lodged in the Australian Museum.

Figure 20. Drainage pattern and location of sample sites.

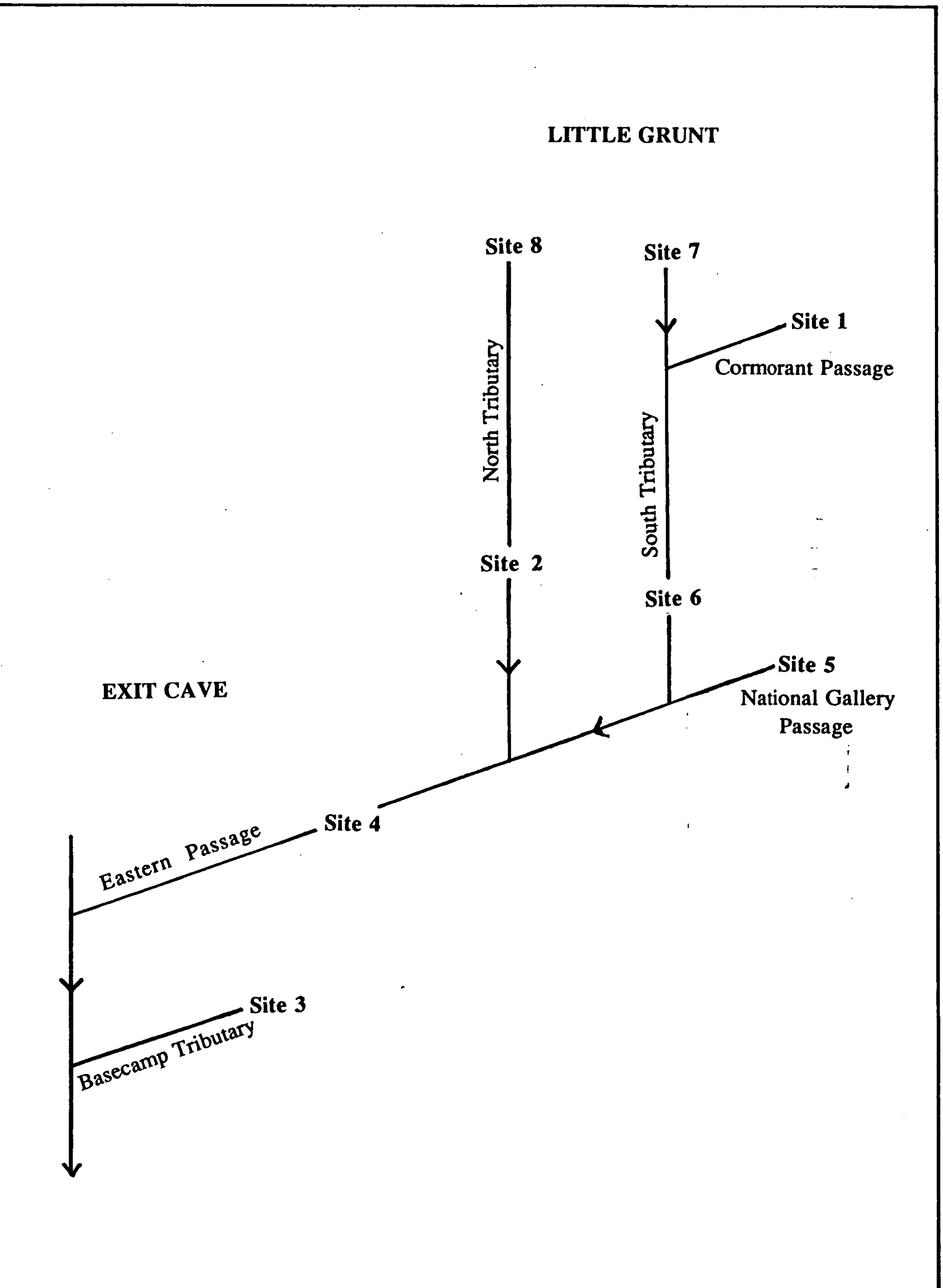


Figure 21. Mean densities of hydrobiids in pools and riffles at each site. Standard error bars shown.

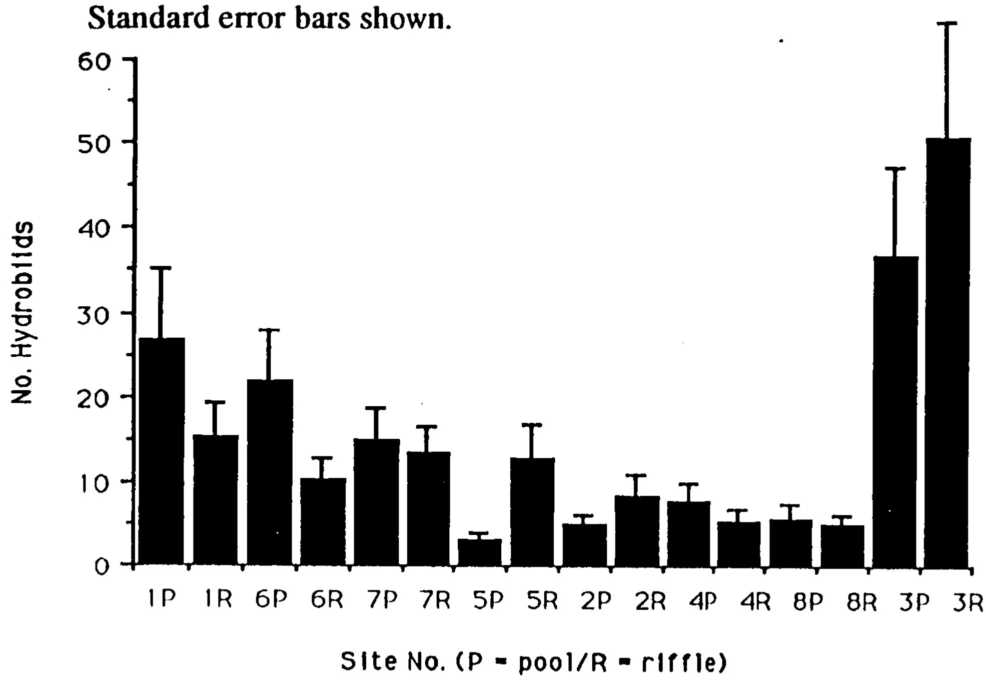
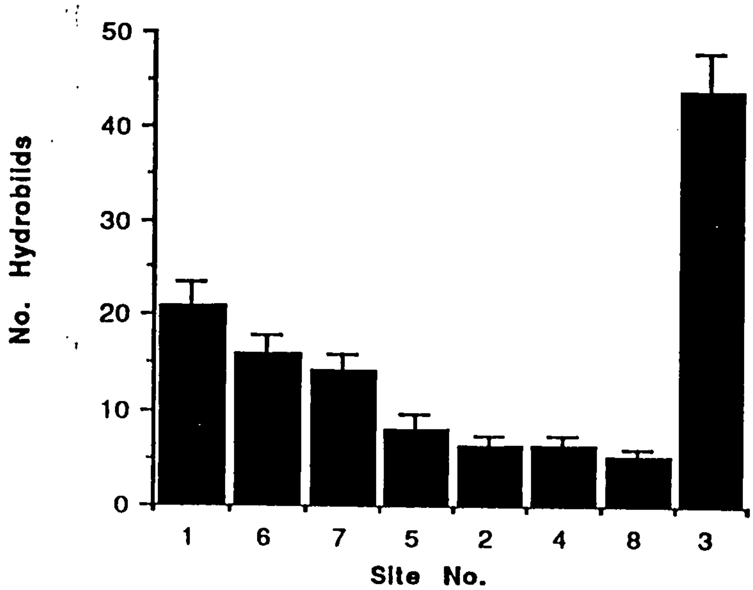


Figure 22. Mean densities of hydrobiids at sample sites (riffles and pools combined). Standard error bars shown.



The mean density of hydrobiids in pools and riffles at each site are shown in Figure 6.2. The number of hydrobiids counted in each quadrat varied from zero to 67. Site 3 (the Base Camp Tributary) was the richest site. The sediment affected sites (Nos. 8, 2 & 4) were the most depauperate. A weak relationship was found between the density of hydrobiids and the % silt cover estimated at each site ($p = 0.0323$).

The assumptions of the ANOVA were tested, the frequency histogram showed a log normal distribution, so the data were transformed to log (x+1). The transformed data showed no relationship between means and variance. The variances in the transformed data were tested using a Cochran's test and were found to be homogenous ($C = 0.25$, $n = 8$, $P > 0.05$). A two way ANOVA between sites and habitats showed that interaction between sites and habitats is significant ($p = 0.0001$). This can be interpreted that there is no site related relationship between hydrobiid densities in pools compared with riffles. Instead, the data were combined for pools and riffles at each site (Figure 6.3), and a one factor ANOVA was used to test the null hypothesis that there is no difference in the density of hydrobiids between sites. This was significant ($p = 0.0001$), and hence there is a statistically significant difference between sites.

A multiple comparison test (Fisher PLSD) grouped the sites with respect to hydrobiid densities, as follows: 3 > $\underline{1\ 7\ 6}$ > $\underline{5\ 4\ 2\ 8}$. Site 3 (Base Camp Tributary) was the richest site, and it is hydrologically independent of all the other sites. Sites 1, 7 & 6 are part of the Southern Tributary Passage in Little Grunt. Sites 8, 2 & 4 are the sites which contain the fine silt and which are relatively depauperate in hydrobiids..

Other aquatic taxa identified were: *Anaspides* sp., plus an unidentified species of amphipod (Family Paramelitidae) and flatworm. These three taxa were recorded from non silted sites. Two of these taxa(*Anaspides* sp. and Amphipoda sp.) were found in the Eastern Passage (Site 4), but only *Anaspides* sp. was seen in the North Tributary in Little Grunt (Sites 2 & 8). I make no inferences from these data.

5.3.6 Discussion

The density of hydrobiid snails in the North Tributary Passage of Little Grunt and the Eastern Passage of Exit Cave is significantly lower than the densities in the South Tributary Passage of Little Grunt and the Base Camp Tributary of Exit Cave.

These lower densities may be correlated with deposits of fine sediment which occur in these sites, but which do not occur at the other sites. The fine sediment blankets the underlying rock substrate and appears to render the habitat less suitable for hydrobiids because they dwell (and presumably feed) on the clean rock surfaces. Alternatively, differences in water chemistry and flow characteristics between sites may affect the distribution and abundance of hydrobiids.

The grouping of Site 5 with the sediment affected sites is unexpected. This site is not affected by fine sediment but did show low densities of hydrobiids, mostly in pools. This anomalous data may be because this site contained patchy and ill-defined habitat zones. Alternatively, the stream at this site may not be perennial like all the other sites, and this might affect the distribution and abundance of hydrobiids

The results obtained for the % of silt cover in quadrats is unlikely to be accurate because the method of visual estimation was imprecise. The type of silt cover may be a more important factor influencing the distribution of hydrobiids. At the pristine sites the substrate was consolidated, with fine sediments composed of sand and gravel-sized particles between the interstices of pebbles and cobbles. The sediment affected sites in contrast, were characterised by deposits of very fine-grained and mobile sediment which blanket all, or part of, the underlying rock substrate. In addition, all bare rock surfaces in the sediment affected streams were coated with a fine, silty "scum" which could be rubbed off by the fingers. This scum bears a resemblance to deposits I have seen in Bradley Chestermans Cave, and which may be associated with the gross pollution and extinction of aquatic fauna there.

5.3.7 Conservation

The International Union for the Conservation of Nature (IUCN) applies a set of status categories to threatened organisms. 'Vulnerable' taxa are those believed likely to move into the 'endangered' category in the near future if the causal factors continue operating. All cave forms of *Anaspides* should be regarded as 'vulnerable', solely on the basis of their highly restricted distributions (O'Brien 1990). Using the IUCN scheme, the populations of hydrobiid snails and other aquatic species which occur in the North Tributary of Little Grunt and the Eastern Passage of Exit Cave are 'endangered', viz. taxa in danger of extinction and whose survival is unlikely if the causal factors continue operating. Run off from the quarry has the potential for causing further destruction of aquatic cave fauna in Little Grunt and Exit Cave, as it already has in Bradley chestermans Cave.

5.3.8 Environmental Indicators and Ecological Monitoring

I know of no other studies which have used hydrobiid snails as environmental indicators in cave streams. The results of this study suggest that they are sensitive to sedimentation, or to other physico-chemical changes associated with the sedimentation. Thus, they have potential to be used as an indicator species in ecological monitoring of the Exit Cave system (but they would not necessarily be the only species monitored). Further sampling or monitoring should be undertaken at different times throughout the year, which should also incorporate different flow regimes. It would be worthwhile, for instance, to investigate possible effects of spate flows on the hydrobiids, because scouring of organisms from the stream bed is more likely, and acidity is likely to be greater (Houshold 1992).

An ecological monitoring programme at Ida Bay is likely to be a long term project, but the methods used here have proven to be both simple and effective, and such methods could be used in other cave systems which contain populations of hydrobiids.

Increased sedimentation is a known anthropogenic impact on stream caves (Kiernan 1988). Sediment may be mobilised from quarries, but it can also be mobilised by other causes, such as forestry operations (Taylor 1991) and by people walking along cave streamways. The impact of cavers on sensitive stream environments and their fauna remains to be investigated, but these impacts have the potential to be significant and deleterious. In the protection and management of caves there is tremendous scope for investigating and minimising such impacts.

5.4 Conservation and management of the Kubla Khan Cave system

5.4.1 Introduction

This section describes the biological resources in Kubla Khan and Genghis Khan Caves, defines their relative importance, and outlines management considerations for the protection of these resources. The biological resources as defined here include the faunal communities found in the cave and the distribution and microhabitat preferences of species, including the types of substrate on which they are found. This survey is limited to macroinvertebrate animals.

Kubla Khan Cave is located about 12 km west of the township of Mole Creek in central north Tasmania. It is a State Reserve administered by the Department of Parks, Wildlife and Heritage. The cave consists of greater than 2 km of passage, including a river and fossil upper level passages with abundant speleothems. Genghis Khan Cave is not so extensive, but genetically it is part of the same system.

Biological interest in Kubla Khan dates back more than 30 years, initially with the discovery of a "White Fish" which is described in some detail by Scott (1960).

The fish proved to be a very pale, feebly pigmented specimen of the introduced trout, *Salmo trutta.* Scott noted the strikingly emaciated condition of the specimen, as well as other abnormal features. Stomach contents of the fish comprised one specimen of *Anaspides tasmaniae.* I am unaware of any other published literature dealing with the biology of Kubla Khan, apart from brief references made to Scott's work above, by Williams (1965) and Goede (1967).

Management of ecological diversity and stability requires evaluation of the habitat characteristics, in addition to knowledge of the organisms themselves. Poulson & Kane (1977) suggest that evaluation of habitat characteristics should include the kinds of food input and a general assessment of amounts, as well as the kinds of substrate. In general, more kinds of substrate mean more habitat types and thus more potential kinds of organisms and more places to hide. Each kind of food input supports a different terrestrial subcommunity of organisms (Poulson 1977). Some species are unique to a subcommunity and others broadly overlap across subcommunities but with their centre of abundance associated with one food input type. Aquatic ecosystems have less distinct subcommunities (Poulson 1977).

This survey of Kubla Khan and Genghis Khan Caves aimed to identify the fauna, evaluate the habitat characteristics and kinds of substrate, and make recommendations for their conservation and management. It was one of the most comprehensive biological resource inventories done in a Tasmanian cave. The other resources and management issues for the system are described in Spate (1991).

5.4.2 Methods

The methods included direct observation, baiting and trapping techniques. Surveying by direct observation involved a thorough search of all accessible areas of floor, walls and roof. Particular attention was given to recognised microhabitats including logs, litter and organic deposits, mud and sediment banks, tree roots, pools, watercourses and underneath stones. The distribution and habitat preferences for each species were recorded. A total of 35 bait stations were installed in the lower entrance chamber and associated passages, and in Cairn Hall passage sections. These were checked for fauna, respectively, 6 days and 13 days later. Baits used were sweet potatoes, blue vein cheese, and kippers in brine (this last bait proved highly attractive to both terrestrial and aquatic cavernicoles). A drift net was installed for a period of 13 days in the River Alph, immediately below the entrance chamber. The net contents were collected and examined immediately following a minor flood on Day 7, and upon final removal. Field work consisted of 9 separate day visits to either Kubla Khan or Genghis Khan Caves, totalling 33 hours in Kubla Khan, and 5 hours in Genghis Khan.

5.4.3 The Fauna

Seventy one taxa of invertebrates were recorded from Kubla Khan and Genghis Khan Caves (see Appendix 5). This included 3 species each of flatworm and springtail; 5 species each of annelid, myriapod and mollusc; 6 species of crustacean, 21 arachnid species and 23 insect species. At least 19 of these species, and probably more, were accidental cavernicoles. Minimally 11 species were troglobites, whilst a further 2 species were possibly troglobitic. The diversity of species was amongst the highest recorded from a Tasmanian cave.

5.4.4 Habitat characteristics

The mechanisms for food input may be biotic or abiotic in origin, discussed separately below.

Biotic input

Biotic input organisms include cave crickets, accidental cavernicoles, mammals (including humans), and roots from plants above the cave.

Cave crickets shelter in caves during the day, but at night a portion of the population moves outside to feed. Carcasses of crickets, cricket guano and eggs from breeding colonies introduce food into the cave. Two species of cave cricket, in the genera *Micropathus* and *Parvotettix*, occured in the cave system. Compared to other cave systems however, total population numbers appeared to be quite small.

Accidental cavernicoles comprise species which normally live in surface habitats but which may wander or be swept into caves. They are an important food source for many permanent cave inhabitants. Accidentals are swept into the cave system through the Grunter Swallets, or enter through the large lower entrance of Kubla Khan. Relatively few enter through the small entrances of Genghis Khan or Kubla Khan's upper entrance. Accidentals identified on this survey included species of grasshoppers, cockroaches, amphipods, beetles, flatworms, millipedes, molluscs, isopods, earthworms, mayflies, caddis flies and various types of insect larvae.

Native mammals provide food input to the cave ecosystem. The abrupt vertical shaft of the lower entrance has proved to be a pitfall trap for possums, wallabies and snakes, and probably other species. The upper entrance and Genghis Khan entrance do not act as such ideal pitfall traps. Skeletons of rodent-sized animals were found scattered throughout the cave, and two bat skeletons (*Nyctophilus geoffroyi*) occur in the Dulcimer Chamber.

Cavers transport organic material into the system. Fragments of litter and leaves are tracked through from the upper entrance. Sheets of paper marking cave survey stations are an additional food source. These scattered fragments attract cavernicoles, including *Styloniscus* sp., Collembola and Symphyla. Animal densities in the upper level sections between Cairn Hall and Mount Arbora appeared to be very low, and the amounts of this kind of food input to the system were relatively minor.

Tree roots are another biotic input organism. Tree roots penetrate the ceilings in the upper entrance section of Kubla Khan and in Genghis Khan. They support a very rich and specialised subcommunity of small invertebrates, including springtails, mites, isopods and bugs. Some species, such as the aphids and other bugs, were found exclusively in tree roots.

<u>Abiotic input</u>

Abiotic food input includes gravity input of litter at entrances, but mainly input of organic matter associated with water (*e.g.* diffuse input by percolating water, semi-concentrated flow around breakdown below surface sinkholes or valleys, and concentrated input from vertical shafts or sinking streams or backflooding) (Poulson & Kane 1977).

Gravity input of logs and litter is a major process occurring in the lower entrance of Kubla Khan Cave. It provides a major habitat and food source for fauna in this region of the cave. There is some gravity input of litter through Genghis Khan's entrance, and essentially no input through Kubla Khan's upper entrance. Nutrient input into the cave may, in part, have been modified by the sandbagging in the antechamber and the low concrete wall remaining from the earlier barrier.

The lower entrance chamber supports a thriving community of cavernicoles, which is directly dependant upon the input of logs and litter, and its associated fauna of accidentals. Evidently, maintenance of the surface vegetation surrounding the entrance is essential for nourishing this log and litter subcommunity. The lower entrance chamber and related passages supports the highest diversity and density of species, including troglobites, in the cave. Some disturbance caused by caving parties is happening in this area. The unstable boulder slope and log matrix is being avalanched down slope. Apart from being directly destructive to the fauna itself, the avalanching greatly reduces the structural complexity (and hence ecological diversity) of the habitat here. The habitat area available to this subcommunity is being reduced by people following numerous different routes across the slope. The solution is to keep traffic to a single route along the northern side of the chamber.

There is potential input of organic matter by percolating water in both Kubla Khan Cave and Genghis Khan Cave. In the latter it is the only type of non-abiotic input. Percolation waters occur in many parts of Kubla Khan, including the upper and lower entrance passages, Sallys Folly, Pleasure Dome and elsewhere. There appears to be little introduction of particulate organic matter by these routes, although silt and charcoal fragments have been transported, presumably by seepage flow, into Forbidden City. Symphylids were found here, but otherwise this section of the cave is extremely food-poor and supports very little fauna.

Perhaps the most significant food input into Kubla Khan Cave comes from sinking streams and associated backflooding. The Grunter Swallets and other feeder streams transport large quantities of nutrients into the cave system. In addition to the aquatic fauna, there is a distinct terrestrial subcommunity which inhabits the walls and sediment banks alongside the River Alph. The majority of species comprising this riparian subcommunity are troglobitic. Taxa recorded include isopods, springtails, symphylids, beetles, pseudoscorpions, harvestmen and amaurobiid spiders. The habitat area of this subcommunity is sharply demarcated, being restricted to the zone of moist substrate immediately above water level. In Cairn Hall, the upper limits of this zone correspond to the maximum level of backflooding. On this survey, the level approximated two metres above normal stream level. Above this level, the sediment banks were drier and few animals were found. The boundaries of this habitat zone are dynamic, and are related to the seasonal flooding regime. Trampling damage to these sediment banks needs to be minimised by route demarcation.

5.4.5 Kinds of substrate

In general, more kinds of substrate mean more habitat types and thus more potential kinds of organisms and more places to hide (Poulson and Kane 1977). Major substrate types identified in Kubla Khan and Genghis Khan were:

-riffles and pools in the River Alph
-seepage fed pools
-flowstone
-sediment banks (sand and silt) associated with the River Alph
-breakdown (with and without clay)
-tree roots
-logs and litter.

Seepage fed pools were prominent throughout the cave including in the Pleasure Dome, Silk Shop, Forbidden City, Mount Arbora, Jade Pool, upper and lower entrance passages and in Sallys Folly. They are a potential habitat of a specialised fauna which consists of syncarids, amphipods, flatworms and molluscs. The pools in Sallys Folly and Forbidden City appeared most suitable for fauna, and they should be managed accordingly. Sallys Folly is the most vulnerable site because people walk through the pools.

Flowstone was rarely a favored substrate for animals, except where organic litter or other food sources (including prey animals) occurred on it, or nearby. The niches in formations offer hiding places for animals, and anchor points for spider webs, for example, many spiders spin webs in flowstone wall deposits on the first and second pitches of the upper entrance. Large areas of breakdown (with and without clay) occur in the Xanadu Chamber. There was little fauna here, presumably due to the paucity of food input.

Moist sediment banks associated with the River Alph, tree roots, logs and organic litter are all important substrates which support rich subcommunities.

5.4.6 Recommendations

Cave stream communities are especially vulnerable to pollution (Poulson 1977). In 1981 for example, a serious environmental catastrophe occurred in Missouri when a pipeline break spilled liquid ammonia nitrate and urea fertilizer into a karst drainage basin (Crunkilton 1984). The spill caused a massive kill of subterranean aquatic organisms in Maramec Spring, a distance of 21 kilometres from the break site. Thus, for management of Kubla Khan's biological resources, the importance and sensitivity to disturbance of the feeder streams and catchment area must be recognised. For instance, where the Grunter Swallet stream passes beneath the Liena Road is a potentially vulnerable point. Any spills of toxic substances occurring on the road here, however unlikely this may be, could be devastating to the cave stream fauna. Likewise, the feeder stream which is presumed to come from Howes Cave drains through agricultural land. Potential impacts could derive from here, whether it be changes to flow regime and water quality, increased sediment loads and consequent sedimentation, nutrient enrichment or toxins (*e.g.* pesticides).

Kubla Khan and Genghis Khan Caves contain a wide variety of habitats and substrate types which support a great diversity of species. There is a rich troglobitic fauna. For conservation and management purposes, the most important habitat areas are:

Kubla Khan Cave:

- the upper entrance area down to the base of the second pitch.
- the lower entrance chamber and associated passages in the log and litter habitat.
- the River Alph and riparian sediment banks, particularly in Cairn Hall.
- the River Alph itself.
- potentially Sallys Folly (if fauna is present).

Genghis Khan Cave:

- the entrance and all upper regions of the cave containing tree roots.

One habitat area which is currently threatened is the log and litter deposits resting on the steep slope of the lower entrance chamber. As discussed above, this is being avalanched down slope by caving parties needlessly using different routes across the slope. To preserve the integrity of this important habitat and subcommunity traffic should be limited to a single route along the northern side of the chamber. This route is the most frequently used although it is easy to miss. The greatest habitat destruction has already occurred along this track. Trampling of sediment banks in Cairn Hall needs to be minimised by demarcating a route. Care needs to be exercised in the upper entrances of Kubla Khan and Genghis Khan because there is abundant fauna which is vulnerable to being "squashed". Spider webs and tree roots are fragile and easily broken. Logs and litter deposits should not be interfered with.

CHAPTER 6 CONSERVATION AND MANAGEMENT PRIORITIES FOR TASMANIAN CAVES

In a report on the conservation status of Tasmanian invertebrates, Greenslade (1985) gives high priority to cave fauna. In reporting on the fauna of the Southern Forests, Statham (1987) recognises cave fauna as a special category worthy of further study. The Forestry Commission recognises the special value of caves in its Code of Forest Practice, and conservation of cave invertebrates is considered in forest practices manuals (Taylor 1990; 1991).

Several cave species are totally protected under the National Parks and Wildlife Act 1970 (Statutory Rule No. 88 of 1976). The species involved are: beetles (*Idacarabus* spp., *Goedetrechus mendumae, G. parallelus, Tasmanotrechus cockerilli*); cave crickets (*Micropathus* spp., *Cavernotettix* sp., *Parvotettix* spp.); glowworms (*Arachnocampa {Arachnocampa} tasmaniensis*); harvestmen (*Hickmanoxyomma* spp., *Lomanella* spp.); pseudoscorpions (*Pseudotyrannochthonius typhlus, P. tasmanicus*). All fauna found in caves within State Reserves is wholly protected, but there are many other cave taxa (mostly undescribed) which remain unprotected. Caves are the type localities for 33 species of invertebrates (see Appendix 2).

The syncarid, *Eucrenonaspides oinotheke,* is listed by the IUCN (1986) as 'vulnerable'. The Mountain Shrimp, *Anaspides tasmaniae,* is protected under the Fisheries Act 1959. In reporting on the conservation status of *A. tasmaniae,* O'Brien (1990) classifies all cave forms as 'vulnerable', solely on the basis of their highly restricted distributions. The 'eyeless' form of *Anaspides* in Wolfe Hole (H-x8) merits special consideration. The population of *A. tasmaniae* in Bradley Chestermans Cave (IB4) is 'endangered' (Eberhard 1990a). There are other vulnerable and endangered populations, and some populations have recently become extinct.

Richards (*in* Greenslade 1985) reports that glow-worms have a high conservation value, for scientific reasons and their potential as tourist attractions. Green (*in* Greenslade 1985) lists two species of isopod of particular biogeographic interest: *Echinodillo cavaticus* from Ranga Cave (RA-x1), and *Styloniscus* sp. from Precipitous Bluff caves.

The findings of this study have identified 28 sites which have high conservation value for biological reasons. The list includes sites which have a high intrinsic scientific value, as well as sites which are considered to be threatened, or at risk, under current land use practices. Protection of some sites is urgently required. It should be noted that the absence of a cave area from this list does not necessarily imply lack of zoological value or conservation threat. It often means only that the area has yet to be studied.

There are more than 60 other karst areas which were not covered by this survey, some of which may contain rare or threatened habitats and species. Further study of many of the sites covered however, may well reveal new data, and new species, as well as identifying additional conservation problems. There are more than 30 documented pseudokarst sites, and many more undocumented (particularly dolerite boulder and talus caves), which, in view of the discoveries on Mount Arthur, may well prove to hold interesting troglobitic faunas. There are abandoned mines and tunnels, such as near Scottsdale, which have been colonised by cave species (including *Hickmania troglodytes* and *Micropathus* spp.) and which may prove to be important refugia for populations, as well as potential study sites. All these areas could benefit from zoological survey for conservation and management reasons.

1. Risbys Basin

This karst is threatened by limestone quarrying interests. The cave system has a rich community of invertebrates. The negative impact that limestone quarries have on cave fauna was strongly indicated in the previous chapter. A preliminary survey of Risbys Basin Cave identified 14 species, four of which were troglobites. These included trechine beetles and the rare *Nuncioides* sp. nov. harvestman, which is only known elsewhere from two caves in the Junee-Florentine karst. Risbys Basin is only the third cave site in Tasmania found to contain Onycophora. The cave fauna is of particular interest for biogeographical studies because it is isolated from the main body of the Junee-Florentine karst by the alluvial plain of the Tyenna River. The plain represents a well defined barrier to dispersal of cave species. Hence, the populations of troglobites in Risbys Basin are likely to be genetically distinct from populations in the rest of the Junee-Florentine. There is tremendous scope for comparative studies between them, including of genetics and evolution, dispersal, speciation and biogeography.

The abundant fauna in the Risbys Basin cave system is due, in part, to the streams which flow into it. These streams carry in nutrients such as wood, leaves, detritus and animals. Thus, to maintain the undisturbed integrity of the cave ecosystem it is crucial to maintain the water quality and flow regime, as well as the natural forest in the catchment (particularly around cave entrances and along stream courses).

2. Junee-Florentine Caves. This karst area has many significant caves located within a logging concession. Forestry operations have resulted in soil erosion, sedimentation in cave streams, clearance of vegetation around cave entrances, and dumping of timber debris into caves and sinkholes. A rich cave fauna occurs in these caves. Three caves, and one surface site, are the type localities for four invertebrate species. The impacts of logging operations on cave biota are undocumented, but this needs to be done.

3. Mole Creek Caves. This is an important region with many significant caves which are located on private farmland, forestry reserves and State Reserves. There are land management and land degradation problems in this karst area, including soil erosion and pollution of underground water supplies (Kiernan 1984). Many caves are easily accessible and there is pressure from casual visitors and wild cave tour operators. Little systematic sampling has been carried out here, but it is clear that there is a rich cave fauna, including troglobitic and locally endemic species. Kubla Khan Cave (MC1) for example, has one of the most diversified faunas in the State, consisting of 71 taxa of invertebrates, including eleven species of troglobites. Several genera and species collected from this cave are new to science. There are twelve caves at Mole Creek which are type localities for seven invertebrate species. A comprehensive fauna survey, with a view to identifying important sites and developing conservation strategies is urgently required.

4. Exit Cave karst system.

Situated in a World Heritage Area this is one of the most significant and extensive karst systems in Australia, but the cave fauna is suffering from the impacts of a limestone quarry operation (see Chapter 6). Even though quarry operations were ceased in 1993, rehabilitation and management of this site will be an ongoing problem. Both Mystery Creek Cave (IB10) and Exit Cave (IB14) are subject to heavy visitor traffic resulting in trampling damage to substrates and possibly disturbance to organisms. Mystery Creek Cave is the type locality for the glowworm, *Arachnocampa (Arachnocampa) tasmaniensis* Ferguson. The glow-worm displays in IB10 and IB14 are unparalleled in Australia. IB10 is the type locality for four other species, whilst IB14 is the type locality for one species. Both caves have a high degree of biological importance (Richards & Ollier 1976), and the whole Ida Bay karst area holds one of the richest assemblages of cave obligate species known in Tasmania. Management planning for the Exit Cave karst system must consider the conservation of biological resources.

5. Bradley Chestermans Cave (IB4)
The effects of quarry run off on this cave include sedimentation, gross pollution and extinction of aquatic fauna. The population of *Anaspides tasmaniae* in IB4 is 'endangered'. Rehabilitation of the quarry site should incorporate biological monitoring of this cave.

6. Loons Cave (IB2).
Loons cave has a rich troglobitic fauna, but is subject to uncontrolled visitor traffic which is causing damage to substrates and possible disturbance to organisms. Habitat and fauna conservation for this cave is a priority.

7. Arthurs Folly Cave (IB110).
IB110 contains a rich troglobitic fauna which is vulnerable to disturbance by cavers. It is the locality for a troglobitic springtail belonging to a new genus and species within the Troglopetini (Collembola: Paronellidae) (P. Greenslade pers. comm.). Habitat and fauna conservation is a priority.

Arthurs Folly Cave, Loons Cave and Bradley Chestermans Cave share a species of troglobitic isopod, *Styloniscus* sp. n. which appears to feed on tree roots, a fragile habitat vulnerable to disturbance. Ascomycete fungi associated with the tree roots in these three caves are also an important invertebrate habitat. Visitor management plans for these caves need to be undertaken soon.

8. Mount Cripps Caves. This is a highly cavernous karst area located in a logging concession. Preliminary sampling in Philrod Cave (CR3) has indicated the existence of a rich cave fauna, including troglobitic species. Forestry management plans should include a comprehensive survey of the Mount Cripps cave fauna.

9. Nelson River Caves. This is a small but highly cavernous limestone outcrop. Part of the outcrop may be flooded as a result of dam construction on the King River. The caves have provided important evidence in elucidating the Pleistocene glacial history of the West Coast region, and one of the caves contains evidence of Pleistocene human occupation (Kiernan 1983). Biological sampling of these caves has been limited to a single brief visit (Eberhard 1988a), further investigations are warranted.

10. Huon Cave (SP1). This is the only significant cave recorded in the Scotts Peak karst area. It is located within the South West Conservation Area, but lies just outside the boundary of the Western Tasmania World Heritage Area. At least half of the passage in this small cave is now inaccessible, following the bulldozing of fill into one of the entrances. This cave is the type locality for the troglobitic species of harvestman, *Hickmanoxyomma goedei* (Hunt 1990); this population is 'vulnerable'. Protection of this population, and management of this site needs to be considered.

11. Flowery Gully Cave (FG201) and Flowery Gully karst area. The cave is situated on private land and has a depauperate fauna. It has been partly destroyed by quarry operations which have now ceased. The cave stream is polluted by run off from surrounding pasture. At least one of the cave species, *Arachnocampa (Arachnocampa) tasmaniensis,* is known to be locally extinct. Dispersal opportunities for some of the terrestrial cave species may have been much reduced, if not completely severed, by conversion of the surrounding native forest vegetation into pasture. A species of harvestman, *Hickmanoxyomma tasmanicum* is known from this cave. It appears to be a cave-isolate population, which is genetically distinct from surface populations to the east of the Tamar River, and may well prove to be a separate species (Hunt 1990). Another species recorded from FG201 is a rare springtail, *Anurida* sp., which is possibly a troglobite (P. Greenslade pers. comm.). An unidentified species of blind isopod is also known. The populations of cave species in FG201 and other Flowery Gully caves are 'vulnerable'. Protection of this site, and other caves at Flowery Gully, needs to be considered.

12. Sherrils Cave (E201). This is the only known cave in the small and isolated Eugenana karst area. The cave is on private land, surrounded by pasture and rural development. One entrance of the cave has been used in the past for dumping of carcasses. At least two species of troglomorphic cavernicole persist here, a spider (Amaurobiidae Gen. *et* sp. n.) and a psocid. These species, and other cave-isolate populations in E201 are 'vulnerable'. Protection of this site needs to be addressed.

13. Rum Pot (G-x3) and other caves in the Gray-Mount Elephant karst area. These caves are developed in Permian limestones, where virtually the only significant fluvial cave development has occurred in the eastern part of Tasmania. It is very isolated from other karst areas in the West. The caves are located on private farmland, and some cave entrances have been filled in. Two species of stygobiontic crustacean are known from G-x3: *Eucrenonaspides* sp., and a genus and species which is close to *Hurleya*. Both these species are 'vulnerable'. Bottomless Pit (G-x1) is the type locality for *Pterocyrtus striatulus* and *Tasmanorites elegans*. Conservation of these sites needs to be considered. This

karst area encompasses part of the distributional range of the Blind Velvet Worm, a species of rare onycophoran (Mesibov 1988, Mesibov & Ruhberg 1991).

14. Mount Arthur Boulder Caves (Lost World Caves). These include Lost World Grotto, Dolerite Delight and other extensive fissure cave systems developed amid dolerite columns. Situated at approximately 1000 m altitude, this is the highest recorded cave community in the State. The community includes cave spiders (*Hickmania troglodytes)* and cave crickets (*Micropathus tasmaniensis*). In addition, these caves harbour a population of highly troglomorphic harvestmen assigned to the genus *Notonuncia* (G. Hunt pers. comm.) The Lost World Caves are the first dolerite boulder caves in Tasmania found to support a troglobitic species. This type of cave habitat occurs widely in Tasmania and future investigations could prove to be rewarding.

15. Gunns Plains karst area.

This karst area is potentially threatened by farming and forestry practises. Gunns Plains Tourist Cave (GP1) is biologically important for the unusual occurrence of a breeding population of the Giant Freshwater Crayfish, *Astacopsis gouldi*. The crayfish are an attraction on the cave tour, and the cave probably serves as a local refuge from fishing for this species. Whilst the cave entrance is situated in a State Reserve, the catchment extends into private farmland and forest land. The population of *A. gouldi* in this cave is 'vulnerable'. Old timber in this cave should not be removed because it is a food source for the crayfish. GP1 is also significant for containing a large deposit of bat bones, although the same species do not colonise limestone caves in Tasmania at present. Fauna conservation at Gunns Plains is needed, particularly with respect to farming and forestry practises.

16. Trowutta Arch (T201). This karst feature is located within a State Reserve. It is a flooded sinkhole with associated underwater passages and an unusual phreatic habitat, which supports an exceptionally rich community of subterranean crustaceans, including phreatoicids, syncarids and amphipods. The reserve boundaries do not cover the whole catchment for this site and land clearance extends virtually to the edge of the sinkhole. Cattle roam into the forest immediately surrounding the doline and there are thistles growing beneath The Arch.

17. Loongana karst area.

The Loongana caves have a high biological conservation value. More than 46 species are recorded, including seven troglobites and the highest diversity of cave dwelling amphipod species recorded in Tasmania, three genera and five species. The caves are located on farmland and forestry areas. The effect of forestry and the establishment of pine plantations in the catchments of caves has likely altered the water quality and flow regimes, with consequent impacts on the cave fauna. Mostyn Hardy Cave is one of only two sites in the State where troglomorphic enicocephalids (Hemiptera) have been recorded. This cave is the most frequently visited at Loongana, with tracking of mud and trampling of substrates evident. In addition to the impact of recreation, other management issues for the Loongana karst include the potential impacts of forestry operations in the catchment areas of caves, the erodibility of residual limestone soils and geomorphic hazards associated with accelerated sinkhole development and road building (Eberhard 1991).

18. Redpa Caves. This small and isolated karst area is situated on private land. Cattle are fouling cave entrances and water supplies; this needs to be controlled. Part of the biological interest of the area lies in the potential for comparative investigations with the Montagu Caves which are located nearby. Both areas are geologically and geomorphologically similar, but unlike Redpa, Montagu has not been subject to land clearance disturbance. The native vegetation surrounding the caves has been cleared for pasture and the cave isolate populations at Redpa are 'vulnerable'.

19. Montagu Caves

These caves are located within a Forest Reserve, but they are still threatened by potential quarrying interests. They contain invertebrate fauna as well as Pleistocene vertebrate remains (Murray & Goede 1977). Further biological surveying is warranted.

20. Ranga Cave (RA-x1). This cave is located on private land on Flinders Island. It is important for being the type locality of an isopod species, *Echinodillo cavaticus,* which is of some biogeographical interest (Green *in* Greenslade 1985). It is also the type locality of a species of cave cricket, *Parvotettix rangaensis*. The conservation status of this site needs to be investigated.

21. Cape Barren Island

A pothole (CB-x1) developed in Pleistocene dune limestone (Matthews 1985), contains crickets, *Cavernotettix flindersensis* and *Parvotettix rangaensis* (Richards 1971a). The conservation status of this site needs to be assessed.

22. King Island karst

King Island has extensive deposits of Pleistocene dune limestone with many freshwater springs. There is potential for pollution of groundwater resources. The spring and groundwater fauna remains unsampled, but could prove to be interesting.

23. Iron Monarch Cave.
This is a sea cave developed in igneous rocks on King Island. It is important as a bat roosting site, which however, is vulnerable to disturbance from visitors. The cave is suffering degradation from casual visitors. This site is important for geomorphological values as well (Goede *et al.* 1979), and protection measures need to be considered.

24. Judds Cavern (Wargata Mina) and the Cracroft caves. This cave, and other caves in the Cracroft karst area have a high scientific and cultural value. There is a rich invertebrate fauna and the caves contain important bone deposits, including the remains of Tasmanian Tiger (*Thylacinus cynocephalus*) (Goede 1977b), and several bat species (Savva & Taylor 1986). Geomorphological studies have provided information on drainage evolution in a Tasmanian glaciokarst (Kiernan 1989b). Wargata Mina contains important archaeological resources (Jones *et al.* 1988), and the Cracroft karst is a popular recreational and exploration caving area. Management planning must address the scientific and recreational values, in addition to aboriginal cultural values.

25. Moina karst area.
An area of Gordon limestone, privately owned and partly flooded by the Lake Gairdner hydro power scheme. The karst and fauna which has not been flooded may still be threatened, and its conservation status needs to be assessed.

26. Lorinna karst area.
An area of Gordon limestone, privately owned and partly flooded by the Mersey-Forth hydro power scheme. The karst and fauna which has not been flooded may still be threatened, and its conservation status needs to be assessed.

27. Jukes-Darwin karst area.
Two stream caves with fauna are known (Matthews 1985, Richards 1968b). The conservation status of this area needs to be assessed because the caves are readily accessible.

28. Julius River
This karst area is situated in a Forest Reserve. Crayfish have been reported from the caves here, and a biological survey is warranted.

6.1 Minimum impact techniques for fauna conservation

6.1.1 Collecting Ethics

There are ethical arguments involved with collecting and killing animals for scientific research purposes. It could be argued that this is justifiable when it benefits the conservation of the species. Some species of cave animals may potentially suffer from the impact of collecting a large number of specimens. This is because the species may only occur in one cave or karst drainage system, it's reproduction rate may be low, and the number of individuals in the population may be relatively few. Collectors must therefore consider the potential impact of their research. Identifying animals whilst they are in their natural habitat, and then leaving them undisturbed, is the ideal solution. This is not always possible however, because specimens must sometimes be collected in order to confirm a species identity, or so that it may be scientifically described.

I believe that limits to collecting must be set on a case by case basis, so that the number of specimens removed from one cave population does not deleteriously impact the viability of that population. The impact of collecting can be minimised for example, by spreading the collection across a number of different caves, or populations. Collectors should thoroughly research any previous collections to avoid unnecessary duplication of effort.

When undertaking a biological survey in a new cave, the collection of a single voucher specimen is usually adequate (this specimen can be kept alive for possible later release in the same cave, in exchange for a taxonomically more useful specimen, for example, of sex or age class). If additional specimens are subsequently required then the collector can return to the cave. The number of additional specimens collected however, should be kept to an absolute minimum. The abundance of the population should be assessed by searching the entire cave first, before deciding on the number of specimens which can be safely collected.

6.1.2 Vulnerable habitats and species

<u>Entrance zones</u>

Entrance zones are shelter for large numbers of invertebrates, for example, cave crickets and the Tasmanian cave spider. Spider webs are vulnerable to breakage and cave crickets are easily disturbed by people passing through.

<u>Sediment banks</u>

Sediment banks, especially alongside streamways, are an important habitat for many taxa, including beetles, spiders, symphylids, springtails and others. These habitats are vulnerable to trampling and compaction damage.

Organic litter

Organic litter in caves is a food source and habitat for cavernicoles. It may be vulnerable to trampling or other disturbance. Wood in old tourist caves should not be removed without first assessing the potential impact on cave communities.

Tree roots and fungi

Tree roots and ascomycete fungi associated with the roots are an important habitat. Some species are found only on tree roots. The fungi and tree roots are fragile structures which are easily broken.

Seeps and low energy streamways

These are habitat for crustacea, molluscs, flatworms and other species. They are vulnerable to trampling and sediment mobilisation.

Seepage pools

Seepage pools are the prime habitat of the rare syncarid *Eucrenonaspides*, and other species.The pools are easily damaged or destroyed by trampling.

Small passages

The substrate and fauna in small passages is vulnerable to the scraping and smearing action of cavers bodies as they crawl along.

Boulder slopes

Boulder slopes, particularly in entrance zones, provide a structurally complex habitat which is utilised by web spinning spiders and other species. Boulder slope habitats are at risk from caving parties causing destabilisation of the slope and avalanching of material. Apart from being directly destructive to the fauna itself, the avalanching greatly reduces the structural complexity (and hence ecological diversity) of the habitat.

Low roofs with glowworms

Glowworm's snares hang from roofs, often above streamways, and are susceptible to breakage and entanglement of the long, sticky threads as cavers brush past them.

6.1.3 Minimum Impact Caving Techniques

Every person that visits a cave probably causes some degree of disturbance to the animals that live there. Many small cave invertebrates live on passage floors, where they are difficult to see but easily trampled on! Continued trampling and compaction of cave sediments for example, alters the habitat characteristics and may threaten the existence of some cave communities. There are some simple techniques which can be practised, to minimise our impact when we visit caves:

Move slowly and deliberately at all times, and look carefully before putting your feet, hands or body anywhere. Scan the area ahead for small animals, and minimise scraping or smearing your body along cave passages. In low passages move on the points of your appendages (like a lizard!) rather than dragging yourself along. This technique requires more energy but does much less damage to the cave. Likewise, carry, rather than drag, your items of equipment.

Get people to watch each other, and warn of nearby delicate formations or fauna. Near entrances, look out for spider webs and avoid breaking them. Also near entrances, look out for cricket colonies and move quickly and quietly away from them. Avoid shining you light at them as this disturbs them. Also avoid sudden movements, loud noises or vibrations. Do not pass underneath cricket colonies with a carbide lamp on (turn it off and use an electric light). Be careful when passing beneath glowworm colonies, to avoid entanglement of the threads.

Keep to the established path or follow a single defined route through passages, keeping in the footsteps of the person in front of you. Consider installing route markers, pathways, barriers or voluntary "no go" areas with explanatory signs.

Avoid trampling of soft sediments or other fragile surfaces. Step or climb on hard surfaces such as the limestone bedrock or boulders. Avoid dislodging rocks from boulder slopes, and refrain from boulder-trundling, or dropping rocks down shafts to test their depth.

Walk in the water of large streamways in preference to sediment banks along the side, but avoid stirring up sediment - step gingerly and don't drag your feet. In small streamways and seepages, avoid walking in the water altogether. Where possible, bridge across the stream using solid rock for support, and don't dislodge rocks and sediment into the water. Step across small pools, and if you must walk through one then do it slowly and carefully.

Do not leave food scraps, candle wax or other rubbish in caves, and do not dump carbide, even into flowing streams, because it is poisonous to cave life.

Educate others about minimum impact caving techniques, especially when underground.

Cave Softly !

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Appendix 1: Tasmanian karst localities
(from Kiernan 1988)

The only parakarst and pseudokarst localities included are four for which biological data are available, but there are many others known. Rock type, area name and area code are given. Areas for which biological data are available are indicated by "s".

Map No.	Area Name	Area Code	Data (s)
PRECAMBRIAN DOLOMITE			
1	Hastings	H	s
2	Mount Anne	MA	s
3	Upper Weld	UW	s
4	Mount Weld	MW	s
5	Tim Shea	TS	
6	Mount Mueller	MM	
7	Gell-Alma (=Cheyne Range)	GA	
8	Mount Ronald Cross	MR	s
9	Frenchmans	FC	
10	Lightning Plains	LP	
11	Everlasting Hills	EH	
12	Carbonate Creek	CC	
13	Jane Goldfields	JG	
14	Upper Erebus Rivulet	UE	
15	Staff Hill	SH	
16	Scotchfire Creek	SC	
17	Erebus-Denison	ED	
18	Upper Peak Creek	UP	
19	East Maxwell-Algonkian	EM	
20	West Maxwell-Algonkian	WM	s
21	Lower Maxwell	LM	
22	Rocky Boat Harbour	RB	
23	Forest Hills	FH	
24	Scotts Peak	SP	s
25	Trowutta	T	s
26	Julius River-Lake Chisholm	JR	s
27	Blackwater-Arthur	BA	
28	Montagu	M	s

29	Scotchtown	ST	
30	Redpa	R	s
31	Savage River	SR	s
32	The Needles	TM	
33	Upper Styx	US	
34	Jubilee Ridge	JB	s
35	Glovers Bluff	GB	
36	Blakes Opening	BO	
37	Lower Cracroft River	LC	
38	Sandfly Creek	SY	
39	Strike Ridge	ST	
67	Acheron River	AR	s
ORDOVICIAN LIMESTONE			
40	Eugenana	E	s
41	Flowery Gully	FG	s
42	Lorinna	LO	s
43	Loongana	L	s
44	Mole Creek	MC	s
45	Moina	M	s
46	Gunns Plains	GP	s
47	Lake Lea [Vale of Belvoir]	LL	
48	Sophia	SO	
49	Mount Cripps	CR	s
50	St Valentines Peak	SV	
51	Junee-Florentine	JF	s
52	Ida Bay	IB	s
53	Cracroft	C	s
54	Surprise Bay	SB	
55	Precipitous Bluff	PB	s
56	Ile du Golfe	IG	s
57	Dubbil Barril	DB	
58	Bubs Hill	BH	s
59	Nelson River	N	s
60	Fincham	FN	
61	Governor	GV	
62	Dante Rivulet	DR	
63	Jukes-Darwin (Bird River)	JD	
64	Upper King	UP	
65	Hazell Creek	HC	
66	Queen-King	QK	
68	Goodwins Creek	GC	

69	Upper Andrew	UA	
70	Lower Andrew	LA	s
71	Spence River	SR	
72	Eagle Creek	EC	
73	Lower Gordon	LG	
74	Butler Rivulet	BR	
75	Franklin	F	s
76	Gordon-Sprent	GS	s
77	Lower Olga	OL	
78	Middle Olga	MO	
79	Nicholls Range	NR	s
80	Wright River	WR	
81	Timbertop Creek	TT	
82	South Loddon	SL	
83	Modder River	MD	
84	Giblin Valley	GI	
85	Vanishing Falls	VF	s
86	Picton	P	
87	Zeehan	Z	
88	Vale of Rasselas	VR	
89	Frankland River (=Davey River)	FR	
90	Cook Creek (Abrotanella Rise)	AB	
91	Bobs Knobs	BK	
92	North Lune (Mesa-Gleichenia)	NL	s
93	Mesa Creek	MS	
94	Lune West	L	

DEVONIAN LIMESTONE

100	Guy Fawkes Creek	GF	
101	Point Hibbs	PH	
102	Hibbs River	HR	
103	Queenstown	Q	
104	Lake Sydney	LS	

PERMIAN LIMESTONE

110	Gray (Mount Elephant)	G	s
111	Maria Island	MI	

CAINOZOIC LIMESTONE AND PLEISTOCENE AEOLIANITE

120	Ranga	R	s
121	North-West Coastline		
122	Marrawah-Redpa	MH	
123	Cape Barren Island	CB	

Pseudokarst

154	Louisa Bay: sea cave, Precambrian metamorphics
171	Mt. Wellington (Lost World): boulder caves, Jurassic dolerite
174	Francistown, Dover: boulder cave, sandstone
222	Devonport spring: Tertiary basalt

Appendix 2: Type localities

Listed below are the caves (or karst sites), and the described species for which they are the type locality. Published references are given in brackets after the species name.

Mystery Creek Cave (IB10)
Arachnocampa (Arachnocampa) tasmaniensis (holotype) (Ferguson 1925; Harrison 1966)
Hickmanoxyomma cavaticum (holotype) (Hickman 1958; Hunt 1990)
Cyphon doctus (holotype) (Lea 1910)
Idacarabus troglodytes (holotype) (Lea 1910)
Tasmanorites flavipes (holotype) (Lea 1910; Moore 1972a)

Exit Cave (IB14)
Goedetrechus mendumae (holotype) (Moore 1972a)

King George V Cave (H-x6)
Pseudotyrannochthonius tasmanicus (holotype) (Dartnall 1970)

Newdegate Cave (H-x7)
Idacarabus cordicollis (holotype) (Moore 1967)

Damper Cave (PB1)
Idacarabus longicollis (holotype) (Moore 1978)
Hickmanoxyomma cristatum (paratype) (Hunt 1990)

Quetzalcoatl Conduit (PB3)
Hickmanoxyomma cristatum (holotype) (Hunt 1990)

Cueva Blanca (PB4)
Hickmanoxyomma cristatum (paratype) (Hunt 1990)

Cashions Creek Cave (JF6)
Goedetrechus parallelus (holotype) (Moore 1972a)

Gelignite Pot (JF391)
Tupua troglodytes (holotype) (Platnick 1990; Forster *et al.* 1990)

Unidentified limestone cave, Florentine Valley
Micropathus tasmaniensis (holotype) (Richards 1964a)

Nichols Spur, Junee-Florentine (surface site)
Parvotettix maydenaensis (holotype) (Richards 1971a)

Gordon River Valley (surface site; on karst?)
Olgania excavata (holotype) (Hickman 1979)

Bottomless Pit (G-x1)
Pterocyrtus striatulus (holotype) (Sloane 1920)
Tasmanorites elegans (holotype) (Moore 1972a)

Unidentified sandstone cave, Francistown, Dover
Micropathus kiernani (holotype) (Richards 1974)

Marakoopa Cave (MC120)
Micropathus cavernicola (holotype) (Richards 1964a)

Little Trimmer Cave (MC39)
Parvotettix goedei (holotype) (Richards 1968b)

Scotts Cave (MC52)
Cryptophagus troglodytes (holotype) (Lea 1910)

Georgies Hall Cave (MC201)
Pseudotyrannochthonius typhlus (holotype) (Dartnall 1970)
Tasmanotrechus cockerilli (holotype) (Moore 1972a)

Baldocks Cave (MC32)
Hickmanoxyomma gibbergunyar (holotype) (Hunt 1990)

Honeycomb Cave (MC84)
Hickmanoxyomma gibbergunyar (paratype) (Hunt 1990)

Wet Cave (MC144)
Hickmanoxyomma gibbergunyar (paratype) (Hunt 1990)

Herberts Pot (MC202)
Hickmanoxyomma gibbergunyar (paratype) (Hunt 1990)

Cow Cave-Pyramid Cave link (MC46)
Hickmanoxyomma gibbergunyar (paratype) (Hunt 1990)

Westmoreland Cave (MC-x64)
Hickmanoxyomma gibbergunyar (paratype) (Hunt 1990)

Mole Creek caves (unspecified)
Hickmanoxyomma gibbergunyar (paratype) (Hunt 1990)

Mole Creek cave (Chudleigh district, on property of Mr F. Henry in 1883)
Hickmania troglodytes (holotype) (Higgins & Petterd 1883; Forster *et al.*1987)

Ranga Cave (RA-x1)
Parvotettix rangaensis (holotype) (Richards 1969)
Echinodillo cavaticus (holotype) (Green 1963)

Unidentified cave, Strzelecki Peak, Flinders Island
Cavernotettix flindersensis (holotype) (Richards 1967b)

Virgo Cave (MR202)
Micropathus montanus (holotype) (Richards 1971a)

Cave (GP4)
Micropathus fuscus (holotype) (Richards 1968b)

Col-In-Cavern (MA1)
Tupua cavernicola (holotype) (Forster *et al.* 1990)
Hickmanoxyomma eberhardi (holotype) (Hunt 1990)

Deep Thought (MA10)
Hickmanoxyomma eberhardi (paratype) (Hunt 1990)

Annakananda (MA4)
Hickmanoxyomma eberhardi (paratype) (Hunt 1990)

Meltwater Pot (MA20)
Hickmanoxyomma eberhardi (paratype) (Hunt 1990)

Cave (MA14)
Hickmanoxyomma eberhardi (paratype) (Hunt 1990)

Huon Cave (SP1)
Hickmanoxyomma goedei (holotype) (Hunt 1990)

Judds Cavern (C1)
Hickmanoxyomma clarkei (holotype) (Hunt 1990)

Matchlight Cavern (C2)
Hickmanoxyomma clarkei (paratype) (Hunt 1990)

Appendix 3: Taxonomists who identified material.

Onycophora
Drs N. Tait & D. Briscoe: School of Biological Sciences, Macquarie University, N.S.W.

Isopoda (Oniscoidea)
A. Green: Tasmanian Museum & Art Gallery, GPO Box 1164M, Hobart 7001.

Isopoda (Asellota)
Dr P. Horwitz: Department of Geography and Environmental Studies, University of Tasmania.

Amphipoda
Dr A. Richardson: Zoology Department, University of Tasmania.

Decapoda
Dr P. Hamr: Inland Fisheries Commission, Tasmania.
Dr P. Horwitz: Department of Geography and Environmental Studies, University of Tasmania.

Collembola
Dr J. Ireson: Department of Primary Industry, New Town Research Laboratories, St Johns Ave, New Town 7008 Tasmania.
Dr P. Greenslade: CSIRO Division of Entomology, PO Box 1700, Canberra City, ACT.

Trichoptera
J. Jackson: Zoology Department, University of Tasmania.

Orthoptera
Dr A. Richards: School of Zoology, University of New South Wales, PO Box 1, Kensington 2033.

Diptera
Dr P. McQuillan: Department of Primary Industry, New Town Research Laboratories, St Johns Ave, New Town, Tasmania.

Coleoptera
Dr B. Moore: c/ CSIRO Division of Entomology, PO Box 1700, Canberra City, ACT.

Pseudoscorpionida
Dr M. Harvey: Arachnology Department, Western Australian Museum, Francis Street, Perth 6000.

Opiliones
Dr J. Hickman: c/ Zoology Department, University of Tasmania.
Dr G. Hunt: Australian Museum, Division of Invertebrate Zoology, PO Box A285, Sydney South 2000.

Araneae
Dr M. Gray: Australian Museum, Division of Invertebrate Zoology, PO Box A285, Sydney South 2000.
Dr N. Platnick: American Museum of Natural History, Central Park West at 79th Street New York, New York, U.S.A.

Mollusca
Dr W. Ponder: Australian Museum, Division of Invertebrate Zoology, PO Box A285, Sydney South 2000.

Appendix 4: Cave invertebrate fauna of Tasmania, by karst area.

This appendix lists the invertebrate fauna collected in Tasmanian caves during this and other studies, by karst area. The karst areas are numbered following Kiernan (1988), and they are grouped by geology.

Where the ecological status of a species is known, this is indicated by one of the following abbreviations. Tb: troglobite; Tp: troglophile; Tx: trogloxene; Ac: accidental; Ed: edaphobite; Sb: stygobiont; Sp: stygophile; TpII: second level troglophile (*sensu* Hamilton-Smith 1971); see Section 1.7.

PRECAMBRIAN DOLOMITE

1 Hastings

Phylum Platyhelminthes: Turbellaria: Tricladida

Paludicola

Order Opiliones

Hickmanoxyomma cavaticum (Tb)
Lomanella sp. n. (Tb)
Calliuncus spp

Order Pseudoscorpionida

Pseudotyrannochthonius tasmanicus (Tp)

Order Araneae

Amaurobiidae
Hickmania troglodytes
Tupua bisetosa (Tp)

Order Acarina

(close to) Macrochelidae sp. indet.
Oribatidae sp. indet.
Uropidae spp. indet.

Class Crustacea

Anaspides tasmaniae (telson 'normal' type) (Sp)
Anaspides sp. (telson 'cave' type) (Sb?)
Eucrenonaspides sp. or spp. indet. (Sb)
Styloniscus sp. nov. B
Styloniscus nichollsi
Styloniscus ?nichollsi

Class Diplopoda

Lissodesmus modestus (Ac/Tx?)
Lissodesmus sp. (Ac/Tx?)

Class Insecta

Coleoptera

Idacarabus cordicollis (Tb)
Idacarabus sp. n. A (Tb)
Idacarabus spp. (Tb)
Staphylinoidea sp.

Phylum Mollusca
Phrantela aff. sp. A

2 Mount Anne

Order Opiliones
Hickmanoxyomma eberhardi (Tb)
Order Pseudoscorpionida
Pseudotyrannochthonius sp nov. (near *P. tasmanicus*) (Tb)
Class Crustacea
Anaspides sp. (telson type intermediate)
Styloniscus squarrosus
Class Diplopoda
Diplopoda spp.
Class Chilopoda
Chilopoda spp.
Class Symphyla
Symphyla spp.
Class Insecta
Collembola
Novacerus sp.
Coleoptera
Tasmanotrechus sp. (near *T.* sp. n. B) (Tb)
Idacarabus sp. n. B (Tb?)
Staphylinidae spp.
Diptera
Arachnocampa (Arachnocampa) tasmaniensis

3 Upper Weld

Phylum Aschelminthes
Nematomorpha
Order Opiliones
Lomanella sp. n. (Tp)
Order Pseudoscorpionida
Pseudotyrannochthonius sp nov. (near *P. solitarius*) (Tp)
Order Araneae
Amaurobiidae
Hickmania troglodytes
Olgania spp.
Textricellidae sp. indet.
Stiphidiidae Gen. et spp. n.
Class Crustacea
Styloniscidae spp. indet.
Antipodeus '?franklini'
Keratroides vulgaris
Class Diplopoda
Diplopoda spp.
Class Insecta
Orthoptera
Micropathus spp.

4 Mount Weld

Class Crustacea

Phreatoicoidea sp. (Sp?)
Antipodeus 'stygobiont 2'

Class Diplopoda

Diplopoda spp.

Class Insecta

Orthoptera

Micropathus spp.

5 Tim Shea

6 Mount Mueller

7 Gell-Alma (=Cheyne Range)

Phylum Platyhelminthes: Turbellaria: Tricladida

Paludicola

Order Araneae

Hickmania troglodytes
Stiphidiidae Gen. et spp. n.

Class Insecta

Orthoptera

Micropathus cavernicola

Diptera

Diptera spp.

8 Mount Ronald Cross

Phylum Platyhelminthes: Turbellaria: Tricladida

Paludicola

Order Opiliones

Nuncioides sp. (Tb)
Paranuncia gigantea

Order Pseudoscorpionida

Pseudotyrannochthonius sp. (near *P. tasmanicus*) (Tp)

Order Araneae

Amaurobiidae
Acrobleps sp.
Stiphidion facetum
Stiphidiidae Gen. et spp. n.
Meta sp. (Tp)
Cycloctenus spp.

Class Crustacea

Anaspides sp. (telson type intermediate)
Eucrenonaspides sp. or spp. indet. (Sb)
Antipodeus 'c.f. *wellingtoni*'

Class Insecta

Collembola

Pseudachorutini sp.

Tullbergia spp.
Cryptopygus antarcticus
Cryptopygus caecus
Cryptopygus loftyensis
Isotoma (Parisotoma) spp. ?
Isotoma (Isotoma) sp.
Oncopodura sp.
Coleoptera
Idacarabus sp. n. C (Tb)
Diptera
Arachnocampa (Arachnocampa) tasmaniensis
Diptera spp.
Phylum Mollusca
"*Fluviopupa*" n. sp. G

9 Frenchmans
10 Lightning Plains
11 Everlasting Hills
12 Carbonate Creek
13 Jane Goldfields
14 Upper Erebus Rivulet
15 Staff Hill
16 Scotchfire creek
17 Erebus-Denison
18 Upper Peak Creek
19 East Maxwell-Algonkian

20 West Maxwell-Algonkian
Class Crustacea
Astacopsis franklinii
Class Insecta
Orthoptera
Micropathus spp.
Diptera
Arachnocampa (Arachnocampa) tasmaniensis
Phylum Mollusca
Phrantela n. sp. C
Beddomeia n. sp. C
Beddomeia n. sp. D

21 Lower Maxwell
Phylum Platyhelminthes: Turbellaria: Tricladida
Paludicola
Order Araneae
Amaurobiidae
Hickmania troglodytes
Cycloctenus spp.

Order Acarina
Other Mites (spp. indet.)
Class Crustacea
Anaspides tasmaniae (telson 'normal' type) (Sp)
Koonungidae ?Gen. et sp. n. (Sb)
Styloniscus ?nichollsi
Heterias petrensis (Sp)
Austrogammarus 'not *smithi* 2'
Genus ? close to *Hurleya ?*sp.B
Class Diplopoda
Diplopoda spp.
Class Insecta
Collembola
Tullbergia spp.
Orthoptera
Micropathus sp. n. (close to *M. montanus*)
Hemiptera
Hemiptera spp.
Neuroptera
Neuroptera
Coleoptera
Notagonum marginellum (Ac)
Phylum Mollusca
Phrantela n. sp. c.f B
"*Fluviopupa*" n. sp. F

22 Rocky Boat Harbour
23 Forest Hills

24 Scotts Peak
Order Opiliones
Hickmanoxyomma goedei (Tb)
Order Araneae
Hickmania troglodytes

25 Trowutta
Phylum Annelida
Oligochaeta
Class Crustacea
Koonungidae sp.
Hypsimetopinae or Phreatoicidae spp. (Sb)
Heterias sp. (Sb)
Genus ? close to *Hurleya* sp. A
Austrochiltonia australis
Class Insecta
Orthoptera
Parvotettix sp.

Hemiptera
Unidentified Water Strider
Diptera
Diptera spp.
Trichoptera
Trichoptera spp.

26 Julius River-Lake Chisholm
Class Crustacea
Astacopsis sp.
Class Insecta
Diptera
Arachnocampa (Arachnocampa) tasmaniensis

27 Blackwater-Arthur

28 Montagu
Order Opiliones
Nucina sp. or spp. (Tp)
Paranuncia gigantea
Order Araneae
Hickmania troglodytes
Class Crustacea
Koonunga sp.
Genus ? close to *Hurleya* sp. A
Engaeus fossor
Class Insecta
Coleoptera
Staphylinidae spp.

29 Scotchtown

30 Redpa
Phylum Platyhelminthes: Turbellaria: Tricladida
Paludicola
Phylum Annelida
Oligochaeta
Order Opiliones
Glyptobunus sp. (Tb?)
Nucina sp. or spp. (Tp)
Order Araneae
Amaurobiidae
Hickmania troglodytes
Class Crustacea
Styloniscus sp. nov. B
Styloniscidae spp. indet.
Heterias sp. (Sb)
Engaeus fossor

Class Insecta
Orthoptera
Parvotettix sp.
Diptera
Culicidae spp.
Diptera spp.
Phylum Mollusca
Phrantela n. sp. c.f B

31 Savage River
Class Insecta
Orthoptera
Micropathus ?fuscus

32 The Needles
33 Upper Styx

34 Jubilee Ridge
Class Insecta
Orthoptera
Micropathus tasmaniensis
Diptera
Diptera spp.

35 Glovers Bluff
36 Blakes Opening
37 Lower Cracroft River
38 Sandfly Creek
39 Strike Ridge

67 Acheron River
Phylum Platyhelminthes: Turbellaria: Tricladida
Paludicola
Sub-phylum Onycophora
Ooperipatellus insignis
Order Opiliones
Calliuncus spp
Order Araneae
Amaurobiidae
Hickmania troglodytes
Tupua spp. indet.
Pseudanapis sp. (TpII?)
Holarchaea globosa
Stiphidiidae Gen. et spp. n.
Meta sp. (Tp)
Cycloctenus spp.

Order Acarina
Oribatidae sp. indet.
Other Mites (spp. indet.)
Class Crustacea
Styloniscus nichollsi
Hypsimetopinae or Phreatoicidae spp. (Sb)
Genus ? close to *Hurleya* sp. C
?Giniphargus sp.
Class Insecta
Collembola
Tullbergia spp.
Novacerus sp. c.f. *tasmanicus*
Orthoptera
Micropathus cavernicola
Coleoptera
Staphylinidae spp.
Diptera
Diptera spp.
Trichoptera
Trichoptera spp.

ORDOVICIAN LIMESTONE

40 Eugenana
Phylum Platyhelminthes: Turbellaria: Tricladida
Terricola
Order Opiliones
Glyptobunus sp. or spp. (Tp)
Order Araneae
Amaurobiidae
Hickmania troglodytes
Class Diplopoda
Diplopoda spp.
Class Symphyla
Symphyla
Class Insecta
Collembola
Pseudosinella sp.
Psocoptera
Psocoptera
Coleoptera
Staphylinidae spp.
Diptera
Calliphoridae sp.
Diptera spp.
Lepidoptera
Lepidoptera spp.

Hymenoptera
Hymenoptera

41 Flowery Gully

Phylum Platyhelminthes: Turbellaria: Tricladida
Terricola
Phylum Annelida
Oligochaeta
Order Opiliones
Hickmanoxyomma tasmanicum (Tp)
Order Araneae
Hickmania troglodytes
Baalzebub spp.
Class Crustacea
Copepoda
Styloniscus sp. nov. B (Tb)
Styloniscidae spp. indet.
Sub-Class Diplura
?*Campodea* sp. (Ac/Tx?)
Class Insecta
Collembola
Anurida sp.
Onychiurus sp.
Folsomia candida sp. F
Lepidocyrtus spp.?
Adelphoderia spp. (includes troglobites)
Orthoptera
Parvotettix ~~sp.~~
Coleoptera
Staphylinidae spp.
Diptera
Culicidae spp.
Diptera spp.
Lepidoptera
Lepidoptera spp.

42 Lorinna

43 Loongana

Phylum Platyhelminthes: Turbellaria: Tricladida
Paludicola
Terricola
Phylum Annelida
Oligochaeta
Order Opiliones
Mestonia sp. n. (Tb?)
Paranuncia gigantea

Order Pseudoscorpionida
Pseudotyrannochthonius sp. (Tp)
Chthoniidae sp. indet. (Tb?)
Order Araneae
Amaurobiidae
Hickmania troglodytes
Textricella sp.
Order Acarina
Oribatidae sp. indet.
Other Mites (spp. indet.)
Class Crustacea
Copepoda
Styloniscus sp. nov. B
Styloniscus [=HEC LGRSS sp. no. 3]
Styloniscidae spp. indet.
Heterias sp. (Sb)
Antipodeus 'sp. A'
Austrogammarus 'smithi ?'
Austrogammarus 'not *smithi* 1'
Austrogammarus 'not *smithi* 2'
Genus ? close to *Hurleya* sp. A
Keratroides vulgaris
Astacopsis gouldi
Astacopsis sp.
Class Diplopoda
Diplopoda spp.
Class Chilopoda
Chilopoda spp.
Class Insecta
Collembola
Ceratophysella sp.
Tullbergia spp.
Mesaphorura sp.
Isotoma (Parisotoma) spp. ?
Lepidocyrtus spp.?
Troglopetini n. gen. sp. 2 (Tp)

Adelphoderia spp. (includes troglobites)
Neelides sp.
Megalothorax sp.

Ephemeroptera
Ephemeroptera spp.

Orthoptera
Parvotettix sp.

Hemiptera
Enicocephalidae sp. or spp. (Tb)

Hemiptera
?*Mesovelia* sp.
?Cicadelloidea

Diptera
Arachnocampa (Arachnocampa) tasmaniensis
Diptera spp.

Trichoptera
Trichoptera spp.

Phylum Mollusca
Fluvidona n. sp. C
Beddomeia n. sp. B
Beddomeia n. sp. E

44 Mole Creek

Phylum Platyhelminthes: Turbellaria: Tricladida
Paludicola
Terricola

Phylum Annelida
Hirudinea

Phylum Annelida
Oligochaeta

Order Opiliones
Hickmanoxyomma gibbergunyar (Tb)
Glyptobunus ?signatus (Tp)
Glyptobunus ? sp. n. (Tp)
Nucina dispar (Tp)
Paranuncia gigantea

Order Pseudoscorpionida
Pseudotyrannochthonius typhlus (Tb)
Pseudotyrannochthonius sp. (Tb?)
Pseudotyrannochthonius sp. or spp. (Tb)

Order Araneae
Amaurobiidae
Hickmania troglodytes
Tupua bisetosa (Tp)
Icona spp.
Mysmenidae Gen. et sp. n.
Chasmocephalon sp.
Chasmocephalon sp.

Stiphidion facetum
Stiphidiidae Gen. et spp. n.
Metidae sp.
Baalzebub spp.
Linyphiidae

Order Acarina

Other Mites (spp. indet.)

Class Crustacea

Copepoda
Ostracoda
Anaspides tasmaniae (telson 'normal' type) (Sp)
Anaspides sp. (telson type unknown)
Eucrenonaspides sp. or spp. indet. (Sb)
Styloniscus sp. nov. B
Styloniscus nichollsi
Styloniscus ?nichollsi
Styloniscidae spp. indet.
Hypsimetopinae Gen. et sp. n. (Sb)
Hypsimetopinae or Phreatoicidae spp. (Sb)
Antipodeus 'stygobiont 2a'
Antipodeus antipodeus
Antipodeus sp. ?
Talitridae spp. indet.

Class Symphyla

Symphyla

Sub-Class Diplura

Campodeidae sp. indet. (Tb?)

Class Insecta

Collembola

Troglopetini n. gen. sp. 2 (Tp)
Oncopodura sp.
Adelphoderia spp. (includes troglobites)

Psocoptera

Psocoptera

Hemiptera

Enicocephalidae sp. or spp. (Tb)

Hemiptera
Aphididae sp.
Fulgoroidea sp. or spp. (Tp/Tx?)
Coleoptera
Tasmanotrechus cockerilli (Tb)
Tasmanotrechus sp. n. C (Tb)
Trechini spp. indet. (inc. Tbs)
Idacarabus spp. (Tb)
Diptera
Arachnocampa (Arachnocampa) tasmaniensis
Calliphoridae sp.
Monophilus sp.
Diptera spp.
Lepidoptera
Lepidoptera spp.

45 Moina

46 Gunns Plains
Phylum Annelida
Oligochaeta
Order Opiliones
Glyptobunus sp. n. (Tb)
Order Araneae
Amaurobiidae
Hickmania troglodytes
Icona spp.
A. extrilidum
Stiphidion facetum
Baalzebub spp.
Australomimetus sp.
Order Acarina
Hydracarina sp. indet.
Other Mites (spp. indet.)
Class Crustacea
Copepoda
Styloniscus sp. nov. B
Antipodeus 'stygobiont 3'
Austrogammarus 'smithi ?'
Austrogammarus 'not *smithi*'
Astacopsis gouldi

Class Diplopoda
Diplopoda spp.
Class Insecta
Ephemeroptera
Ephemeroptera spp.
Orthoptera
Parvotettix sp.
Hemiptera
Notonectidae
Diptera
Arachnocampa (Arachnocampa) tasmaniensis
Culicidae spp.
?Chironomidae
Diptera spp.
Trichoptera
Hydrobiosidae spp.
Hydropsychidae sp.
Phylum Mollusca
Fluvidona n. sp. D
Beddomeia n. sp. F
Beddomeia n. sp. G
Beddomeia c.f. *hulli*

47 Lake Lea [Vale of Belvoir]
48 Sophia

49 Mount Cripps
Order Opiliones
Lomanella sp. n. (Tp)
Order Araneae
Hickmania troglodytes
Class Crustacea
Copepoda
Class Insecta
Coleoptera
Trechini spp. indet. (inc. Tbs)

50 St Valentines Peak

51 Junee-Florentine

Phylum Platyhelminthes: Turbellaria: Tricladida
Paludicola
Terricola
Phylum Aschelminthes
Nematomorpha
Phylum Annelida
Hirudinea
Phylum Annelida
Oligochaeta
Order Opiliones
Nuncioides sp. (Tb)
Order Pseudoscorpionida
Pseudotyrannochthonius sp. nov. (Tb?)
Pseudotyrannochthonius sp. (near *P. typhlus*?) (Tb)
Order Araneae
Amaurobiidae
Hickmania troglodytes
Tupua troglodytes (Tb)
Olgania spp.
Micropholcomma sp.
Stiphidiidae Gen. et spp. n.
Metidae sp.
Order Acarina
Oribatidae sp. indet.
Class Crustacea
Anaspides tasmaniae (telson 'normal' type) (Sp)
Anaspides sp. (telson 'cave' type) (Sb?)
Anaspides sp. (telson type unknown)
Eucrenonaspides sp. or spp. indet. (Sb)
Styloniscus sp. nov. B
Styloniscus ?nichollsi
Styloniscus [=HEC LGRSS sp. no. 3]
Styloniscidae spp. indet.
Heterias sp. (Sb)
Antipodeus 'stygobiont 3'
Antipodeus 'stygobiont 4'
Antipodeus 'stygobiont c.f. *wellingtoni*'
Antipodeus '?*franklini*'
Antipodeus 'sp. A'
Antipodeus 'sp B'
?*Antipodeus* sp. A
Class Diplopoda
Pseudoprionopeltis hardyi (Ac/Tx?)
Diplopoda spp.
Class Chilopoda
Craterostigmus tasmanianus

Class Symphyla
Symphyla
Class Insecta
Collembola
Australonura sp.
Sinella sp.
Paronellides sp. c.f. *dandenongensis*
Adelphoderia spp. (includes troglobites)
Ephemeroptera
Ephemeroptera spp.
Plecoptera
Eusthenia spectabilis
Eustheniidae sp. or spp.
Plecoptera sp.
Hemiptera
Hemiptera spp.
Neuroptera
Neuroptera
Coleoptera
Goedetrechus parallelus (Tb)
?*Goedetrechus* sp.
Trechini spp. indet. (inc. Tbs)
Percosoma carenoides (Ac)
Diptera
Arachnocampa (Arachnocampa) tasmaniensis
Calliphoridae sp.
Simulidae sp. or spp. indet. (Ac)
Limnophila sp.
Trichocera sp.
Diptera spp.
Trichoptera
Hydrobiosella tasmanica
?*Asmicridea*
Trichoptera spp.
Phylum Mollusca
Phrantela cf. sp. A

"*Fluviopupa*" n. sp. c.f. A
"*Fluviopupa*" n. sp. C
Fluvidona ? n. sp. D

52 Ida Bay
Phylum Platyhelminthes: Turbellaria: Tricladida
Paludicola
Terricola
Phylum Nemertina
Phylum Aschelminthes
Nematomorpha

Phylum Annelida
Oligochaeta
Order Opiliones
Hickmanoxyomma cavaticum (Tb)
Lomanella sp. n. (Tb)
Order Pseudoscorpionida
Pseudotyrannochthonius sp. nov. (near *P. tasmanicus*) (Tb)
Chthoniidae sp. indet. (Tb?)
Afrochthonius australis (Tp)
Protogarypinus sp. nov. (F. Olpiidae) (Tp)
Order Araneae
Amaurobiidae
Hickmania troglodytes
Tupua spp. indet.
Icona spp.
Mysmenidae sp.
Olgania spp.
Anapidae spp.
Textricella sp.
'*Orsinome*' sp. (Tp)
Porrhomma sp.
Order Acarina
Other Mites (spp. indet.)
Class Crustacea
Atopobathynella sp.
Anaspides tasmaniae (telson 'normal' type) (Sp)
Anaspides sp. (telson 'cave' type) (Sb?)
Anaspides sp. (telson type intermediate)
Anaspides sp. (telson type unknown)
Eucrenonaspides sp. or spp. indet. (Sb)
Styloniscus sp. nov. A
Styloniscus sp. nov. B
Styloniscus ?nichollsi
Styloniscus maculosus
Heterias petrensis (Sp)
Heterias sp. (near *petrensis*) (Sb)
Antipodeus 'stygobiont 2a'
Antipodeus franklini
Antipodeus 'sp. A'
?*Antipodeus* sp. B
Genus ? close to *Hurleya* sp. B
Talitrid spp. indet.
Astacopsis franklinii
Class Diplopoda
Diplopoda spp.
Class Symphyla
Symphyla
Class Insecta

Collembola

Troglopetini n. gen. sp. 1 (Tb)
Oncopodura sp.
Neelides sp.

Ephemeroptera

Atalonella sp. (Leptophebiidae)
Ephemeroptera spp.

Hemiptera

Fulgoroidea sp. or spp. (Tp/Tx?)
Hemiptera spp.

Neuroptera

Neuroptera

Coleoptera

Goedetrechus mendumae (Tb)
Tasmanorites flavipes (Ac?)
Idacarabus troglodytes (Tb)

Diptera

Arachnocampa (Arachnocampa) tasmaniensis
Culicidae spp.
Podonomopsis discoceros
?Chironomidae
Sciara sp.
Limnophila sp.
Diptera spp.

Trichoptera

Apsilochorema obliqua
Taschorema sp.
Caloca saneva

Phylum Mollusca

Phrantela n. sp. A
"*Fluviopupa*" n. sp. A
Fluvidona n. sp. A
Fluvidona n. sp. c.f. A
Fluvidona sp.

53 Cracroft

Phylum Platyhelminthes: Turbellaria: Tricladida

Terricola

Phylum Annelida

Oligochaeta

Order Opiliones

Hickmanoxyomma clarkei (Tb)

Order Pseudoscorpionida

Pseudotyrannochthonius sp. (Tb)

Order Araneae

Amaurobiidae
Hickmania troglodytes

Class Crustacea

Anaspides tasmaniae (telson 'normal' type) (Sp)

Eucrenonaspides sp. or spp. indet. (Sb)
Styloniscus sp. nov. B
Antipodeus 'stygobiont 3'
Antipodeus 'sp. A'

Class Symphyla

Symphyla

Class Insecta

Hemiptera

Fulgoroidea sp. or spp. (Tp/Tx?)

Diptera

Arachnocampa (Arachnocampa) tasmaniensis
Diptera spp.

Phylum Mollusca

Beddomeia group

54 Surprise Bay

55 Precipitous Bluff
(see Appendix 5)

56 Ile du Golfe

Order Araneae

Achaearanea spp.
Toxopsiella sp.

Order Acarina

Other Mites (spp. indet.)

Class Crustacea

(close to) *Acanthodillo* sp.
Deto marina
Ligia australiensis

Class Insecta

Collembola

Colosella sp.
Xenylla sp.
Entomobrya sp.

Diptera

Diptera spp.

57 Dubbil Barril

58 Bubs Hill

Phylum Platyhelminthes: Turbellaria: Tricladida

Paludicola
Terricola

Phylum Nemertina

Phylum Aschelminthes

Nematomorpha

Phylum Annelida
Oligochaeta
Sub-phylum Onycophora
Ooperipatellus insignis
Order Opiliones
Hickmanoxyomma sp. or spp. n.
Hickmanoxyomma spp. (Tbs)
Lomanella sp. n. (Tp)
Calliuncus spp
Nuncioides ?infrequens (Tp)
Nuncioides ?dysmicus (Tp)
Nuncioides sp. (Tp)
Glyptobunus sp. or spp. (Tp)
Phoxobunus sp.
Order Pseudoscorpionida
Pseudotyrannochthonius sp. nov (near *P. typhlus*) (Tb)
Pseudotyrannochthonius sp. nov. (near *P. solitarius*) (Tp)
Chthoniidae sp. indet.
Order Araneae
Amaurobiidae
Hickmania troglodytes
Icona spp.
Achaearanea spp.
Phoroncidia sp.
Olgania spp.
Stiphidiidae Gen. et spp. n.
'*Orsinome*' sp. (Tp)
Metidae ?Gen. et sp. n. (Tp)
Baalzebub spp.
Cycloctenus spp.
Order Acarina
Anystidae (*Anystis baccarum*)
Erythraeidae (*Erythrites (Erythrites)* sp.)
Oribatidae sp. indet.
Uropidae spp. indet.
Class Crustacea
Anaspides sp. (telson type unknown)
Styloniscus sp. nov. B
Styloniscus squarrosus
Styloniscus maculosus
Styloniscus hirsutus
Antipodeus 'sp. A'
Keratroides vulgaris
Class Diplopoda
Diplopoda spp.
Class Insecta
Collembola
Hypogastrura purperescens
Lepidophorella sp.

Thysanura
- *Ctenolepisma* sp.

Ephemeroptera
- *Atalonella* sp. (Leptophebiidae)
- Ephemeroptera spp.

Odonata
- *Austroaeschna hardyi*

Plecoptera
- *Eusthenia spectabilis*
- Possibly *Eusthenia costalis*
- *Austrocercella christinae*

Orthoptera
- *Parvotettix maydenaensis*
- *Micropathus cavernicola*

Hemiptera
- *Myzus persicae*

Coleoptera
- *Tasmanotrechus* sp. n. A (near *T. leai*) (Tp)
- *Tasmanotrechus* sp. n. A-1 (near *T. leai*) (Tp)
- *Tasmanotrechus* sp. n. B (Tb)
- *Rhabdotus eflexus* (Ac)
- *Stichonatus leai* (Ac)
- Staphylinidae spp.
- Staphylinidae spp.

Diptera
- *Arachnocampa (Arachnocampa) tasmaniensis*
- Culicidae spp.
- Calliphoridae sp.
- Tribe Tanytarsini
- Chironomidae sp.
- Diptera spp. indet.
- *Limnophila* sp.
- Tipulidae spp.
- Cecidomyiidae spp.
- Probably *Sylvicola* sp.
- *Culicoides* sp.
- Phoridae sp.
- *Sphaerocera* spp.
- Nematocera sp.

Trichoptera
- Hydrobiosidae spp.
- Leptoceridae sp.

Lepidoptera
- *Barea* sp.
- Hepialidae spp. indet.

Hymenoptera
- *Chelaner leae*

Phylum Mollusca

"*Fluviopupa*" n. sp.

59 Nelson River
Order Opiliones
Calliuncus spp
Mestonia ?acris (Tp)
Order Araneae
Hickmania troglodytes
Icona spp.
Meta sp. (Tp)
Class Crustacea
(close to) *Cubaris* sp.
Class Insecta
Collembola
Australonura wellingtonia
Lepidocyrtus spp.?
Ephemeroptera
Ephemeroptera spp.
Plecoptera
Eustheniidae sp. or spp.
Orthoptera
Micropathus cavernicola
Hemiptera
Microvelia sp. or *Rhagovelia* sp.
Diptera
Arachnocampa (Arachnocampa) tasmaniensis
Diptera spp.

60 Fincham
62 Dante Rivulet

63 Jukes-Darwin (Bird River)
Class Insecta
Diptera
Arachnocampa (Arachnocampa) tasmaniensis

64 Upper King
65 Hazell Creek
66 Queen-King
68 Goodwins Creek
69 Upper Andrew

70 Lower Andrew
Phylum Annelida
Hirudinea
Order Opiliones
Hickmanoxyomma sp. (Tb)

Lomanella sp. (Tp)
Order Araneae
Hickmania troglodytes
Tupua spp. indet.
Icona spp.
Acrobleps hygrophilus
Baalzebub spp.
Order Acarina
Other Mites (spp. indet.)
Class Crustacea
Micraspides ?calmani (Sp)
Austrogammarus 'smithi ?'
Austrogammarus 'not *smithi* 2'
Genus ? close to *Hurleya* sp. A
Paraleptamphopus sp.
Class Diplopoda
Diplopoda spp.
Class Insecta
Collembola
Hypogastrura ?purperescens
Ephemeroptera
Ephemeroptera spp.
Orthoptera
Micropathus cavernicola
Hemiptera
Hemiptera spp.
Diptera
Diptera spp.
Trichoptera
Hydrobiosidae spp.

71 Spence River
72 Eagle Creek
73 Lower Gordon
74 Butler Rivulet

75 Franklin
Phylum Platyhelminthes: Turbellaria: Tricladida
Paludicola
Phylum Annelida
Oligochaeta
Order Opiliones
Hickmanoxyomma sp. or spp. n.
Hickmanoxyomma spp. (Tbs)
Lomanella sp. n. (Tp)
Calliuncus spp
Glyptobunus sp. or spp. (Tp)
Paranuncia gigantea

Order Araneae
Amaurobiidae
Hickmania troglodytes
Tupua troglodytes (Tb)
Tupua spp. indet.
Icona spp.
Acrobleps sp.
Mysmena sp.
Olgania spp.
Pseudanapis sp. (TpII?)
Stiphidion facetum
Stiphidiidae Gen. et spp. n.
Meta sp. (Tp)
Baalzebub spp.
Cycloctenus cryptophilus
Australomimetus sp.
Order Acarina
Oribatidae sp. indet.
Other Mites (spp. indet.)
Class Crustacea
Anaspides tasmaniae (telson 'normal' type) (Sp)
Micraspides ?calmani (Sp)
Styloniscus ?squarrosus
Notoniscus sp.
Styloniscidae spp. indet.
Austrogammarus 'sp. a'
Paraleptamphopus sp.
Neorchestia plicibrancha
Parastacoides tasmanicus inermis
Parastacoides sp. (juvenile)
Class Diplopoda
Diplopoda spp.
Class Chilopoda
Chilopoda spp.
Class Symphyla
Symphyla
Class Insecta
Collembola
Lobellini sp.
Ceratophysella sp.
Tullbergia spp.
Lepidocyrtus spp.?
Adelphoderia spp. (includes troglobites)
Orthoptera
Parvotettix sp.
Micropathus cavernicola
Micropathus montanus
Coleoptera
Pterocyrtus sp n. (Tb?)

Diptera
Arachnocampa (Arachnocampa) tasmaniensis
Diptera spp.
Phylum Mollusca
Phrantela n. sp. B

76 Gordon-Sprent
Order Araneae
Icona spp.
'*Orsinome*' sp. (Tp)
Class Crustacea
Styloniscus ?nichollsi
Class Diplopoda
Diplopoda spp.
Class Insecta
Orthoptera
Micropathus cavernicola
Micropathus montanus

77 Lower Olga
78 Middle Olga

79 Nicholls Range
Phylum Platyhelminthes: Turbellaria: Tricladida
Paludicola
Phylum Annelida
Oligochaeta
Order Opiliones
Hickmanoxyomma goedei (Tb)
Lomanella sp. n. (Tp)
Order Araneae
Amaurobiidae
Hickmania troglodytes
Icona spp.
Stiphidiidae Gen. et spp. n.
'*Orsinome*' sp. (Tp)
Baalzebub spp.
Order Acarina
Other Mites (spp. indet.)
Class Crustacea
Anaspides tasmaniae (telson 'normal' type) (Sp)
Heterias sp. (near *petrensis*) (Sb)
Antipodeus franklini
Genus ? close to *Hurleya* ?sp. B
Giniphargus (not *pulchellus*)
Class Diplopoda
Diplopoda spp.

Class Insecta
Collembola
Australonura sp. c.f. *wellingtonia* group
Tullbergia spp.
Ephemeroptera
Ephemeroptera spp.
Orthoptera
Micropathus montanus
Hemiptera
?Cicadelloidea
Coleoptera
Pterocyrtus sp n. (Tb?)
?Staphylinidae sp.
Diptera
(Arachnocampa) tasmaniensis
Lopescladius SRV sp. 39
Simulidae sp. or spp. indet. (Ac)
Diptera spp.
Trichoptera
Trichoptera spp.
Lepidoptera
Lepidoptera spp.
Phylum Mollusca
Phrantela n. sp. D

80 Wright River
81 Timbertop Creek
82 South Loddon
83 Modder River
84 Giblin Valley

85 Vanishing Falls
(see Appendix 5)

86 Picton
87 Zeehan
88 Vale of Rasselas

89 Frankland River (=Davey River)
Order Araneae
Meta sp. (Tp)
Baalzebub spp.
Cycloctenus cryptophilus
Class Insecta
Orthoptera
Micropathus tasmaniensis

Diptera
Diptera spp.

90 Cook Creek (Abrotanella Rise)
91 Bobs Knobs

92 North Lune (Mesa-Gleichenia)
Phylum Annelida
Oligochaeta
Order Opiliones
Hickmanoxyomma cavaticum (Tb)

Order Araneae
Amaurobiidae
Hickmania troglodytes
Metidae ?Gen. et sp. n. (Tp)
Cycloctenus spp.
Class Crustacea
Styloniscus nichollsi
Styloniscus maculosus
Keratroides vulgaris
Class Insecta
Collembola
Tullbergia spp.
Orthoptera
Parvotettix sp.
Micropathus tasmaniensis
Diptera
Arachnocampa (Arachnocampa) tasmaniensis

93 Mesa Creek
94 Lune West

DEVONIAN LIMESTONE

100 Guy Fawkes Creek
101 Point Hibbs
102 Hibbs River
103 Queenstown
104 Lake Sydney

PERMIAN LIMESTONE

110 Gray (Mount Elephant)
Phylum Platyhelminthes: Turbellaria: Tricladida
Terricola
Phylum Nemertina

Order Araneae
Amaurobiidae
Hickmania troglodytes
Order Acarina
Oribatidae sp. indet.

Class Crustacea
Eucrenonaspides sp.
Genus ? close to *Hurleya* sp. indet.
Keratroides angulosus
Class Diplopoda
Diplopoda spp.
Class Insecta
Collembola
Onychiurus sp.
Ephemeroptera
Ephemeroptera spp.
Coleoptera
Tasmanorites elegans (Ac?)
Trechini spp. indet. (inc. Tbs)
Pterocyrtus striatulus (Tp?)
Diptera
Diptera spp.

111 Maria Island

CAINOZOIC LIMESTONE AND PLEISTOCENE AEOLIANITE

120 Ranga
Order Araneae
Cycloctenus spp.
Class Crustacea
Echinodillo cavaticus

121 North-West Coastline
122 Marrawah-Redpa
123 Cape Barren Island

PSEUDOKARST AREAS

Mt. Wellington
Phylum Platyhelminthes: Turbellaria: Tricladida
Terricola
Order Opiliones
Calliuncus spp
Notonuncia sp. n. (Tb)

Order Pseudoscorpionida
Pseudotyrannochthonius sp. (Tp or Acc)
Order Araneae
Amaurobiidae
Hickmania troglodytes
Tupua spp. (near *bisetosa*) (Tp & Tb?)
Icona spp.
Stiphidion facetum
Meta sp. (Tp)
Cycloctenus spp.
Linyphiidae
Class Crustacea
Keratroides vulgaris
Class Diplopoda
Diplopoda spp.
Class Insecta
Collembola
Lepidocyrtus spp.?
Adelphoderia spp. (includes troglobites)
Diptera
Diptera spp.

Devonport spring
Class Crustacea
Eucrenonaspides oinotheke (Sb)

Louisa Bay
Class Insecta
Orthoptera
Micropathus tasmaniensis

Appendix 5: List of fauna, and their ecological status, from different karst systems (refer to Chapter 4 and Chapter 5).

Exit Cave karst system:

Flatworms (Phylum Platyhelminthes)
Freshwater Flatworms (Sub-order Paludicola)
Terrestrial Flatworms (Sub-order Terricola)
Nemertine Worms (Phylum Nemertini)
unidentified species
Horse-Hair Worms (Phylum Nematomorpha)
unidentified species
Segmented Worms (Phylum Annelida)
Earthworms (Class Oligochaeta)
Leeches (Class Hirudinea)
Harvestmen (Order Opiliones)
Hickmanoxyomma cavaticum (Tb)
Lomanella sp. (Tb)
Leionuncia sp.
Pseudoscorpions (Order Pseudoscorpionida)
Austrochthonius australis
Pseudotyrannochthonius sp. (Tb)
Protogarypinus sp.
Spiders (Order Araneae)
Tasmanian Cave Spider (*Hickmania troglodytes*)
Olgania sp. (Tb)
Tupua sp.
Textricella sp.
Porrhomma sp.
Archaeranea sp.
'*Orsinome*' sp.
two species of *Icona* (one Tb)
new genus and species in the Family Amaurobiidae (Tb)
unidentified species belonging to the Families Mysmenidae and Anapidae (Tb)
Mites (Order Acarina)
several unidentified species
Crustaceans (Class Crustacea)
Atopobathynella sp. (Sb)
Mountain Shrimp (*Anaspides tasmaniae*), plus undescibed *Anaspides* sp.

Eucrenonaspides sp. (Sb)
three species of Slater, including *Styloniscus maculosus*, *Styloniscus ?nichollsi* and an undescribed species in the same genus
new species of *Heterias* (Sb)
three new species of aquatic amphipod in the genus *Antipodeus*(one Sb)
unidentified species of terrestrial amphipod in the Family Talitridae
Freshwater Crayfish (*Astacopsis franklinii*)

Millipedes (Class Diplopoda)

At least one new species in the Family Dalodesmidae (Tb), plus an unidentified species

Symphylids (Class Symphyla)

unidentified species (?Tb)

Insects (Class Insecta)

Springtails, including a species of *Oncopodura*
unidentified species of Bug (Order Hemiptera)
unidentified species of Lacewing (Order Neuroptera)
Ten beetle species including *Goedetrechus mendumae* (Tb), *Idacarabus troglodytes* (Tb), *Tasmanorites flavipes, Cyphon doctus, Adelium abbreviatum, Percosoma caranoides, Licinoma* sp. and *Rhabdotus* sp, plus unidentified species of Rove Beetle (Family Staphylinidae) and Water Beetle (Family Hydrophilidae)
Five species of flies, including fungus flies (*Sciara* sp.), fungus gnats (*Arachnocampa (Arachnocampa) tasmaniensis*), midges (*Podonomopsis discoceros*), craneflies (*Limnophila* sp.) and mosquitoes (Family Culicidae)
Three species of caddisflies including *Apsilochorema obliqua, Caloca saneva* and *Taschorema* sp.
Mayflies, including *Atalonella* sp.
Stoneflies, including *Eusthenia* sp.
Cave Crickets (*Micropathus tasmaniensis*)
New species of aquatic snails in the genera *Phrantela, Fluvidona* and *"Fluviopupa"*
Terrestrial snails including *Caryodes dufresni, Tasmaphena sinclairi* and *Bothriembryon tasmanicus*

Precipitous Bluff karst system:

Nematomorpha
(?) *Gordius* sp.
Annelida
Oligochaeta spp.
Mollusca
Caryodes dufresni (Ac)
Tasmaphena sinclairi (Ac)
Stenacapha hamiltoni (Ac)
Prolesophanta dyeri (Ac)
Roblinella sp. (Ac)
c.f. *Miselaoma parvissima* (Ac)
Beddomeia sp. n. A (Sb)
Fluvidona sp. n. B (Sp)
"*Fluviopupa*" sp. n. B (Sp)
n. genus? aff. *Phrantela*, n. sp. (Sb?)
Diplopoda
Dalodesmidae sp. (Tb)
Diplopoda sp. (?)
Symphyla
unidentified sp. (Ed)
Crustacea
Styloniscus sp. B (Tb)
Anaspides sp. (Sb)
Antipodeus sp. (stygobiont 1)
Acarina
unidentified sp. (?)
Pseudoscorpionida
Pseudotyrannochthonius sp. (Tb)
Opiliones
Hickmanoxyomma cristatum (Tb)
Hickmanoxyomma clarkei (Tb)
Mestonia sp. nov. (Tb)
Lomanella. sp. nov. (Tb)
Araneae
Hickmania troglodytes (Tp)
Meta sp. 1 (Tp)
Stiphidiidae Gen. et sp. n. (Tp)
Gen. et sp. nov. 1 (Tp)
Tupua troglodytes (Tb)
Icona sp. (Tb)

Amaurobiidae Gen. et sp. n. (Tb)
Pseudanapis sp. 1 (Tp)

Collembola

Adelphoderia sp.(Tb?)
Troglopetini Gen. n. sp. 2 (Tp)

Ephemeroptera

unidentified sp. (Ac)

Orthoptera

Micropathus tasmaniensis (Tp)

Coleoptera

Idacarabus longicollis (Tb)
Trechini sp. n. (Tb)

Diptera

Arachnocampa tasmaniensis (Tp)
Diptera sp. indet. (Tx)
Diptera larva indet. (?)

Vanishing Falls karst system:

Platyhelminthes

Tricladida (?Sb)

Annelida

Oligochaeta (Sp)

Opiliones

Hickmanoxyomma sp. (Tb)
unidentified sp. (Tb)

Pseudoscorpionida

Pseudotyrannochthonius sp. (Tb)

Araneae

Hickmania troglodytes (Tp)
Metidae (Tp)
Stiphidiidae (Tp)
Gen. et sp. nov. (Amaurobiidae) (Tb)
Icona sp. (Tb)
? Micropholcommatidae (Tb)

Crustacea

Anaspides tasmaniae (Sp)
Anaspides sp. (Sb)
Styloniscus sp. (Oniscidea) (Tb)
Heterias sp. (Janiridae) (Sb)

Amphipoda (Paramelitidae)
Antipodeus sp. (Sb)
unidentified sp. (Sp)
unidentified sp. (Sp)

Diplopoda
Gen. et sp. nov. (Dalodesmidae) (Tb)
unidentified sp. (Tp)

Symphyla
unidentified sp. (?Tb)

Collembola
Entomobryidae (Tb)
Oncopoduridae (Tb)

Orthoptera
Micropathus sp. (Tp)

Coleoptera
Idacarabus sp. nov. (Tb)

Ephemeroptera
unidentified sp. (Ac)

Diptera
Arachnocampa tasmaniensis (Tp)
unidentified sp. (Tx)

Gastropoda
Hydrobiidae
sp. 1 (?Sb)
sp. 2 (Sp)

Kubla Khan Cave karst system:

Platyhelminthes
Terricola sp. 1 (Ac)
Terricola sp. 2 (Ac)
Terricola sp. 3 (Ac)

Annelida
Hirudinea sp. indet. (Ac)
Oligochaeta sp. 1 (Ac)
Oligochaeta sp. 2 (Ed?)
Oligochaeta sp. 3 (Ed?)
Oligochaeta sp. 4 (Ac)

Symphyla
sp. or spp. indet. (Ed)

Diplopoda

sp. 1 (melanic) (Ac)
sp. 2 (large) (Ac?)
sp. 3 (small) (?)
sp. 4 (soft-bodied) (?)

Crustacea

Styloniscidae sp. indet. (Tp)
Styloniscus sp. nov. (Tb)
Talitridae sp. indet. (Ac)
Amphipoda sp. 1 (?)
Amphipoda sp. 2 (Ac?)
Anaspides tasmaniae (Tp)

Opiliones

Triaenonychidae sp. 1 (Tb)
?*Hickmanoxyomma gibbergunyar* (Tb)
Nucina dispar (Tp)
Glyptobunus ?n. sp. (Tp)
Glyptobunus ?*signatus* (Tp)

Pseudoscorpionida

Pseudotyrannochthonius sp. (Tb)

Araneae

Hickmania troglodytes (Tp)
Cycloctenus sp. (Tp)
Baalzebub sp. (Tp)
Amaurobiidae Gen. et sp. nov. (Tb)
Chasmocephalon sp. (Tb)
Mysmenidae gen. nov. (Tb)
Icona sp. 1 (Tb)
Linyphiidae (Ac)
Tupua bisetosa (Tp)
Icona sp. 2 (Tp)
Stiphidiidae Gen. nov. (Tp)

Acarina

sp. indet. 1 (?)
sp. indet. 2 (?)
sp. indet. 3 (?)
sp. indet. 4 (?)

Collembola

Troglopetini n. gen. et sp. (Tp)
Oncopodura sp. (Tb?)
Adelphoderia sp. nov. (Tb)

Hemiptera

?Fulgoroidea sp. indet. (Tp)
Aphididae sp. indet. (Tb?/Tp)

Trichoptera

sp. indet. 1 (Ac)
sp. indet. 2 (Ac)

Ephemeroptera

sp. indet. (Ac)

Blattodea

sp. indet. (Ac)

Lepidoptera

sp. indet. (Tx)

Orthoptera

Micropathus ?cavernicola (Tp)
Parvotettix ?goedei (Tp)
?Acrididae sp. indet. (Ac)

Coleoptera

Trechini sp. indet. (Tb)
Carabidae sp. indet. 1 (Tb)
?Carabidae sp. indet. 2 (Ac)
?Lucanidae sp. indet. (Ac)
Curculionidae sp. indet. (?)
Hydrophiloidea sp. indet. (Ac)

Diptera

sp. indet. 1 (Tx)
sp. indet. 2 (Tx)
sp. indet. 3 (Tx)
sp. indet. 4 (Tx)
sp. indet. 5 (Tx)
sp. indet. 6 (Tx)
Arachnocampa tasmaniensis (Tp)

Mollusca

sp. indet. 1 (?)
sp. indet. 2 (Ac)
sp. indet. 3 (?)
Hydrobiidae sp. or spp. indet. (Tp)
Pisidium casertanum (Ac)

Appendix 6: List of fauna, and fauna - site records, for The Potholes and Bradley Chestermans Cave (refer to section 4.6).

List of cave fauna, and its ecological status, recorded from the study area. Abbreviations: Tb = troglobite, Sb = stygobiont, Tp = troglophile, Tx = trogloxene.

Taxa and species [+ abbreviation]	Status
Tricladida	
sp. or spp. indet. [Pl]	?
Oligochaeta	
sp. or spp. indet. [Ol]	?
Symphyla	
sp. indet. [Sy]	Tb?
Opiliones	
Hickmanoxyomma cavaticum [Hc]	Tb
Lomanella sp. nov. [Lo]	Tb
Pseudoscorpionida	
Pseudotyrannochthonius sp. [Ps]	Tb
Araneae	
Hickmania troglodytes [Hi]	Tp
Olgania sp. nov. [Og]	Tb
Icona sp. nov. [Ic]	Tb
Amaurobiidae Gen. et sp. nov. [Am]	Tb?
Metidae sp. indet. [Me]	Tp
Stiphidiidae sp. indet. [St]	Tp
Anapidae sp. or spp. indet. [An]	?
Tupua sp. [Tu]	Tp
sp. indet. 1 [Hu]	Tp
Acarina	
sp. indet. (near *Microtrombidium* ?) [Ac]	Tp
Collembola	
Troglopetini Gen. et sp. nov. [Tr]	Tb
spp. indet. [Co]	?
Crustacea	
Styloniscus sp. nov. A [Sa]	Tb
Styloniscus sp. nov. B or spp. [Sb]	Tb
Eucrenonaspides sp. [Eu]	Sb
Antipodeus 'stygobiont 2a' [At]	Sb

Diptera	
Arachnocampa tasmaniensis [Ar]	Tp
sp. indet. 1 [Di]	Tx?
sp. or spp. indet. 2 [Dp]	Tx?
Hemiptera	
Fulgoroidea sp. indet. [Fu]	Tp
Coleoptera	
Idacarabus sp. [Id]	Tb
Pselaphidae sp. indet. [Pe]	?
Orthoptera	
Micropathus tasmaniensis [Mi]	Tp
Mollusca	
Hydrobiidae sp. indet. [Hy]	Sb?

Species - site records for The Potholes and Bradley Chestermans Cave. Refer to list above for abbreviation of species names. "x" = present.

														Species																
Cave	Pl	Ol	Sy	Hc	Lo	Ps	Hl	Cg	Ic	Am	Me	St	An	Hu	Tu	Ac	Tr	Cb	Sa	Sb	Eu	At	Ar	Di	Dp	Fu	Id	Pe	Mi	Hy
IB4	x	x	x	x	x		x	x	x	x							x	x	x						x	x		x	x	
IB23		x		x			x	x		x	x				x					x				x			x		x	
IB46				x		x	x	x	x	x					x								x				x		x	
IB51							x				x			x	x									x	x				x	
IB90				x			x			x	x			x	x										x				x	
IB91				x	x		x	x		x	x				x			x		x							x		x	
IB92							x																x						x	
IB93							x							x	x									x		x			x	
IB94				x			x			x	x			x	x			x		x							x		x	
IB96				x			x				x				x														x	
IB97				x	x		x	x		x			x	x	x										x		x		x	
IB98	x			x			x			x	x		x		x					x	x	x					x		x	x
IB99	x			x		x	x			x	x	x	x		x						x			x					x	x
IB100				x			x			x				x	x										x				x	
IB101				x			x			x	x				x														x	
IB104	x			x		x	x	x		x		x	x					x		x	x				x		x		x	
IB117				x			x			x	x	x			x										x	x			x	
IB118				x			x			x	x				x														x	
IB124							x																						x	
IB125				x			x							x	x								x						x	
IB132				x			x			x					x									x			x		x	
IB211				x			x			x		x		x	x										x				x	
CAVE 1							x																						x	
CAVE 3							x																						x	
CAVE 4							x																x							
CAVE 5							x				x																			
CAVE 6							x																						x	
CAVE 7							x																						x	
CAVE 8											x																			
CAVE 9				x			x								x										x		x		x	
CAVE 10				x			x			x	x				x								x		x				x	
CAVE 11							x				x														x				x	
CAVE 12				x			x								x										x				x	
CAVE 13							x																						x	
CAVE 14							x				x			x										x	x					
CAVE 15				x			x				x				x	x							x		x				x	
CAVE 16							x																						x	
CAVE 18							x				x																			
CAVE 19							x			x																			x	
CAVE 20							x																							
CAVE 21							x																						x	
CAVE 22							x																							
CAVE 24							x																						x	
CAVE 25				x			x			x					x														x	
CAVE 26							x																							
CAVE 27							x																							
CAVE 28							x				x																		x	
CAVE 29				x			x								x														x	
CAVE 30				x			x					x																	x	
CAVE 31							x				x				x														x	
CAVE 32							x							x	x														x	
CAVE 33							x				x			x															x	
CAVE 34				x			x			x	x	x			x												x		x	
CAVE 35							x				x																		x	
CAVE 36							x				x				x								x						x	
CAVE 37							x				x	x			x								x						x	
CAVE 38							x				x	x																	x	
CAVE 39				x			x					x			x														x	
CAVE 40							x																						x	
TOTALS	4	2	1	27	3	3	58	6	2	20	26	9	4	11	30	1	1	4	1	5	3	1	8	6	14	3	10	1	50	2